DISCOVERY

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

Dr. Canute

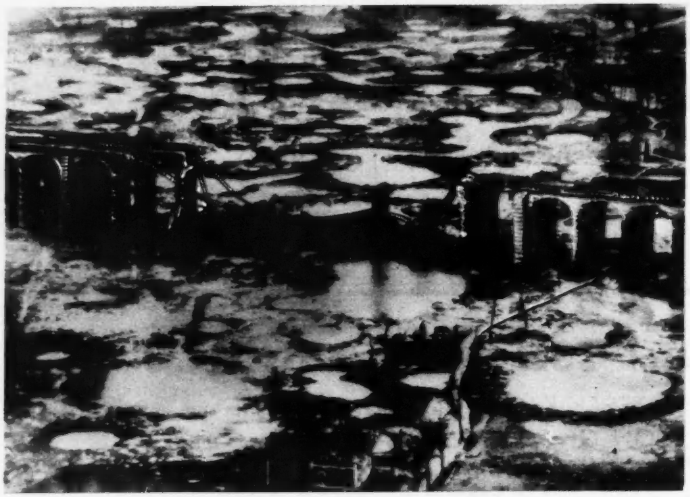
DR. JOAD, in his recent B.B.C. discussion with Professor J. D. Bernal, raised once more the ghost of the Bishop of Ripon in an attempt to stem the rising tide of scientific progress. The discussion (entitled "Should we call a halt to science?") was neither edifying nor original, and came to no satisfactory conclusions. In this connection the B.B.C. itself has a certain responsibility. Was it, after all, the best way to secure discussion of a very serious social problem to ventilate it in this form? On the one hand we had Britain's foremost peripatetic philosopher, who doubtless felt that he was called upon to maintain his well-deserved reputation as a dialectician, and whose nimble and trusted brain produced its usual high-pitched torrent of wit, enabling him to score debating point after debating point. On the other side was a scientist, accustomed to a cautious frame of mind, whose whole training would encourage him to seek the co-operation of his opponent in a search for truth, rather than to score rather superficial points.

And it must be admitted that the discussion was superficial, that it was below the standard of intellectual prowess which we might have expected from either of the disputants taken singly, and that, though it gained in entertainment value, it lost its opportunity of contributing to the maturity of public views on this matter.

On the subject of the discussion itself there is very little to be said, for the important factors can be enumerated simply enough. In order to win the war scientists must devote themselves to the development of new weapons. They do not like doing this, but circumstances force them to it. If the conditions for war were present, then war would come and, though the weapons might be less deadly, there would be correspondingly less protection against them, less protection against starvation, disease and wounds, and far less capacity for speedy reconstruction. If, with Dr. Joad, we see only one side of the medal, then we shall miss the important fact that, although circumstances have made many debit entries in the account of science, the credit items are far greater. In spite of everything, we to-day have a far better prospect of happy, full and healthy lives than at any previous time in the world's history. If we balance the lives saved by improvements in medical, nutritional, and agricultural knowledge—and they run into untold millions—against those lost by the increased deadliness of war, there is no doubt that we have a heavy credit balance.

If fact, the problem depends on what one means by "calling a halt to science". Clearly this slick phrase does not describe the problem at all. What is meant is whether the existing resources of science together with future developments will make it easier or more difficult to get out of the mess we are in and to avoid getting into a new one. Quite clearly we can only get out of our present mess by using scientific resources to the full. Without them we have not the ghost of a chance of rebuilding decent lives for our people, and even with them it is going to be an uphill task. Nobody is going to quarrel with this simple statement—so where is the catch? Why do we fear that this scientific knowledge will turn and rend us later on? It is because we have now displayed before our eyes all the dreadfully ingenious destruction of war, and because we fear the consequences of a new war.

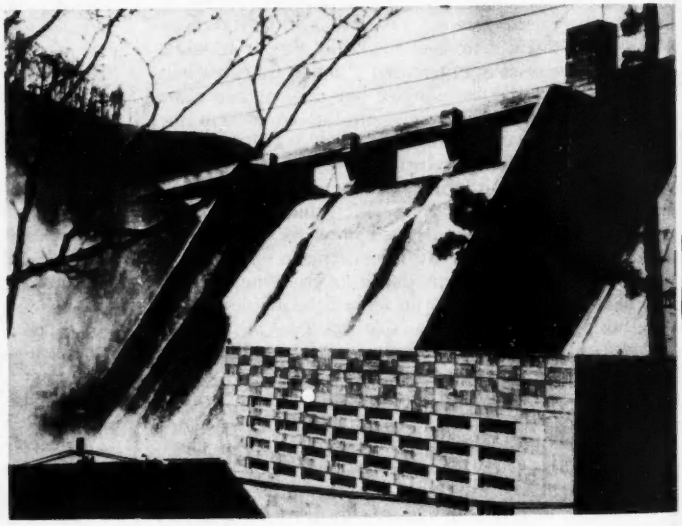
Before we consider that point let us spare one moment to look at the present. It is true that scientific weapons have produced a truly horrible degree of suffering, but the weapons themselves are inert and must be employed for an end by sentient human beings. The nation is at war because it chose war as the better alternative and it has mandated its members to win that war by any means available which will not imperil the peace. It is no use the ordinary man kicking about the way science is being used because he determines it. There has never been a time when scientific effort expressed more exactly the wishes of the community. This is a hard fact, and taken by itself might seem to imply that the ordinary common man shares the devilish appetite for destruction that some would impute to the scientists. That is of course not the case: no one with any imagination can take pleasure in the spectacle of bombs falling on German cities, or wish anything but a speedy end to the whole miserable business. But the responsibility for action is universal: war, for one reason or another, is chosen and, given the choice of war,



Scientific knowledge is a neutral and can be made to destroy or build according to circumstances.

Left.—Intensified application during this war of scientific knowledge to the solution of military problems has effected a crescendo of devastation. This photograph, showing the railway viaduct at Bielefeld after the attack on March 14 in which 10-ton bombs were used for the first time, epitomises the pitch to which aerial bombardment has been brought during the war with Germany.

Below.—The Norris Dam in the Tennessee Valley. TVA, under which a new unity in the development of natural resources has been reached, is an outstanding enterprise in which science and technology has found the fullest use for constructive purposes



scientific knowledge is but one instrument in its prosecution. War with bare hands or spears among the miserable disease-ridden and ignorant few who could scratch a living from an unfriendly earth must have been a ghastly business which went on almost continuously, and an interval of twenty years of peace (a life-time in the misery of the Golden Age of the past) would have seemed like heaven.

The core of the problem is made up of political factors. Scientific knowledge is a neutral and can be made to destroy or build according to circumstances. The whole problem is to remove the political causes of war and hence the incentive to use science for deadly purposes. It has become a truism that applied science plays an important part in the shaping of some of these political factors, especially when it comes into conflict with an existing social system. The cramming of the new wine of science into the old bottles of a system which works inefficiently must lead in the end to a political outburst. If we do not use the gifts of applied science to the full and share the benefits universally we shall court disaster. We shall face a repetition of the economic conditions of artificial scarcity, of unemployment and misery: we shall invite the reappearance of the political diseases of the earth, of the search for temporary advantage especially by the reintroduction of armaments as a prime factor in the economy of the world, and by the invention of creeds of political cozenage which can deceive men into following a course of political action which courts disaster for all.

In all this science is a neutral, but scientists are not. The one striking point made by Dr. Joad was that scientists could not hope to influence the uses made of their work, and this is almost true. They can do much by a combination of forces and by a careful study of the political implications of the utilisation of science, leading to the agreement of politico-scientific policy. But just as the man in the street must take equal responsibility with his scientific representatives for the use of weapons of war, so must he learn to take responsibility for the uses which are made of scientific knowledge in peace-time. The whole problem depends on the growth of an enlightened public opinion, and without that we court disaster indeed. Scientists as a body now realise how these problems are linked, and there is a growing realisation among the general public. It is part of the function of DISCOVERY to foster this realisation, not perhaps suggesting answers to these problems, but rather pointing to their existence and pleading for their most serious consideration.

"As You Were" Television

THE report has been published of the Television Committee, which was appointed in September, 1943 with the following terms of reference:

"To prepare plans for the reinstatement and development of the television service after the war with special consideration of:
(a) the preparation of a plan for the provision of a service to, at any rate, the larger centres of population within a reasonable period after the war;
(b) the provision to be made for research and development;
(c) the guidance to be given to manufacturers, with a view especially to the development of the export trade."

With one exception, the report passes on all the problems to a proposed Television Advisory Committee, which it recommends the Government to constitute from representatives of the Treasury, the Post Office, the Department of Scientific and Industrial Research, and the B.B.C., and with a Chairman of standing.

The one firm recommendation of the Committee is "Reinstatement of the 1939 service in London", with the same 405-line picture scanning system, which was a firm demand from the Radio Industry Council. Since the witnesses who appeared before the Committee were representatives of the R.I.C., of four constituent firms of the radio industry, of the B.B.C. (who were well satisfied with their pre-war television achievements), of the cinema interests (J. Arthur Rank appears twice in the list of witnesses), of the Board of Trade and of the Ministry of Education, and Mr. J. L. Baird, the Committee could hardly have failed to be persuaded by the views of the industry unless it had on its own initiative sought independent advice on the matters of public interest involved. There is a discreet silence as to the method of transmitting the sound accompaniment of the picture, but one infers that the sound also will be on the pre-war system, i.e. will not use the more recent system of Frequency Modulation. However, the advantages to the radio industry of this back-to-1939 decision (or should one say back-to-1936?) are partially nullified by the threat that the Advisory Committee may recommend that the provincial stations (which may be built during the period of 1-6 years after the re-establishment of the London service) should use some other standards of transmission; the manufacturers would then have to supply different types of receiver for London and for the provinces. The Cinema interests apparently do not consider 1939 television good enough to be of any use to them; so the Committee recommends that television definition should eventually be of the order of 1,000 lines, which would suit the cinemas, and Baird is propitiated by adding that "the introduction of colour and stereoscopic effects should be considered."

After stating that patents are of fundamental importance in the development of the television service, the Committee finds it inadvisable to interfere with the operations of industry and merely recommends "that the Advisory Committee should, as opportunity offers, bring its influence to bear on the owners of such patents with a view to ensuring that they are made available for use as the national interest may demand." Having allowed the industry to return to pre-war standards for immediate use, the Committee asks that "research work should begin as soon as possible on the development of a radically improved system of television." Profound thought on the problems of research leads the Committee to the conclusions that the B.B.C. will look after the development of studio equipment, etc., the Post Office will work on the problems of television relaying by cable and radio, the D.S.I.R. will be willing to help, and "pure research" in the Universities might stumble on something useful for television; but, with regard to the co-ordination of *industrial* research, both complete unification in a Research Association and completely free competitive working are rejected in favour of a Government-sponsored compromise, of which the details are to be worked out by the future Advisory Committee.

It is clear that a television service cannot be self-supporting for some years at any rate, although the Committee recommends an additional licence fee of perhaps £1 per year for domestic television receivers. Presumably, then, the Treasury must contribute substantially in one form or another, but the details are gracefully omitted on the ground that a decision must wait until the post-war relationship between Government and B.B.C. is settled. (Before the war the B.B.C. had a percentage of licence revenue; but during the war it has received instead an annual Treasury grant of about three times its pre-war income to cover overseas services and other special war-time expenditure as well as the home services). Exports are now fashionable, and it is natural that the industry should encourage the Government to finance television transmissions by pointing to the value of television to export trade, both as a saleable article and for its prestige value. But when the Committee comes to consider the guidance to be given to manufacturers in relation to export trade, it concludes that the industry itself must be responsible for developing a foreign market in television which is admittedly limited in scope. International standardisation receives lip-service but, being incompatible with back-to-1939 television, it is left for consideration by the future Advisory Committee, although there is a definite plea for international agreement on carrier frequencies (wavelengths) for television.

There is on the whole little indication that the reaction of technical factors on "the public interest" was considered but the report does make the following useful statements on matters of fact which have not been widely appreciated:

"Radiolocation owes much to past research work on television, but war research has produced little information and no discovery of a fundamental character bearing directly on television, although it has very greatly extended the technique of the radio engineer.

"A certain number of men and women who have acquired appropriate experience during the war will no doubt find employment on television, but they will of course constitute only a fraction of the numbers trained in radio work of one kind or another during the war.

"There are, however, limitations to the early development of a large export market which it would be wrong to under-estimate. For some time only industrialised countries with large centres of population will be able to afford television, and some such countries, particularly the United States of America, will manufacture apparatus themselves; but others may be expected to look abroad for supplies if an attractive service can be offered at a reasonable price."

Most welcome to all radio engineers is the recommendation that the Postmaster-General should be given power to suppress electrical interference.

To sum up, the report apparently recommends giving high priority in man-power and materials to the re-establishment of a pre-war service which was then something of a luxury service and is admitted to have only limited value

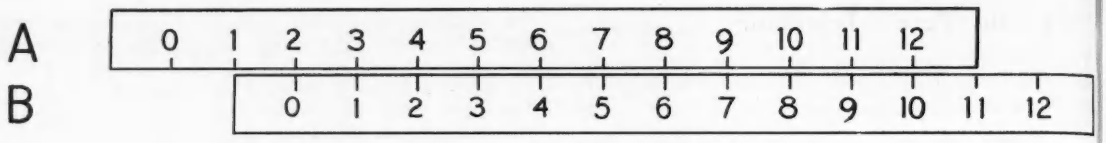


FIG. 1.

for export trade. The return to 1939 is recommended in spite of the knowledge that every other industrial country (including German-occupied France) has made progress in television technique during the year when British television had to be sacrificed to the war effort. No real incentive is provided for either the industry or the B.B.C. to hasten the development of technical improvements: the B.B.C. appears to be satisfied with having led the world in 1936, and suggests that anyway the pre-war receivers did not do justice to its transmissions. It is probably unfortunate that the bulk of the provincial programmes are to be provided by relay from Alexandra Palace, for the concentration of all programmes in one centre will minimise individuality and experimentation in programme production. It is to be hoped that the proposed new Television Advisory Committee will be set up as soon as possible, that it will reach speedier and more definite conclusions on the problems of television, of which some (e.g. patents) will be ten years old, and above all that it will not allow television in Britain to become fossilised.

Fun with Rulers

A RULER is used for measuring things. It has equal spaces marked on it, and at each mark is written the number of inches or centimetres which are covered in a journey from the beginning of the ruler to that particular mark. Nothing could be simpler or more obvious. However, it is possible to have a little mild fun even with rulers graduated in this way. For example, two rulers of the ordinary kind can be used as a simple calculating machine for doing addition and subtraction.

For instance, take ruler A as shown in Fig. 1 and set ruler B against it so that the zero on ruler B comes opposite the '2' on ruler A. This arrangement then serves as a calculating device for adding 2 to any number. Any number, for example the 6 on ruler B, is opposite a number two units greater on ruler A. For adding 2 to any number x therefore read off the number on ruler A which is opposite the x of ruler B. Contrariwise, to subtract 2 from any number y read off the number on B which is opposite the y of ruler A. Obviously we can construct a device for adding or subtracting any number other than 2 simply by displacing the two rulers by the correct amount.

However, real fun only becomes possible when we begin to use crazy rulers graduated in unusual ways. Clearly of course there must be some system in the graduation—complete craziness butters no parsnips—and the simplest of these is probably the logarithmic scale. It may be that the memory of logarithms has faded since the reader's last reading of Hall and Knight but it is fortunately possible to define a logarithmic scale without so much as a mention of the word logarithm.

Suppose we take an ordinary scale such as C (Fig. 2) and label the divisions as shown in the diagram. The characteristic property of this scale is that if we label one mark '1' and another '10', then a further step of the same length brings us to '100' and yet another equal step to '1000'. The system is therefore that equal steps are labelled by equal ratios of numbers. What mark then should we attach to a point such as P half-way between '1' and '10'? The answer is easy enough to find. Each step along the scale of a given length corresponds to a certain *ratio*, just as each step on an ordinary rnler corresponds to a certain *difference*. Suppose the step 1 to P corresponds to a certain ratio x to 1. Then P should be marked with the number 'x'. But from P to '10' is an equal step, also representing a ratio of x to 1. i.e. if P should be marked 'x' then '10' should be the same as $x \times x$, i.e., x is $\sqrt{10} = 3.16$. In an exactly similar way we can show that Q which is one third of the way from '1' to '10' should be marked $\sqrt[3]{10} = 2.15$, and so on. We can in fact find out the mark to be put on any point of the scale which we choose and in particular we can invert the problem and find out where to put the marks for 2, 3, 4, 5 and so on. In addition we can fill in 20, 30, 40, 50 etc., because from '2' to '20' is the same distance as from '1' to '10' the ratio of the numbers being the same in the two cases.

The scale D (Fig. 3) shows a fully graduated scale constructed on this system. Alongside it is shown an exactly similar scale E which is displaced by a distance equal to that from '1' to '2' on the scale. With ordinary rulers A and B a displacement gave us an adding machine which added on to all the numbers of one scale a constant number equal to the displacement. Now our new scales D and E are graduated so that a given step corresponds to a certain *ratio*. If we combine D and E in this way we

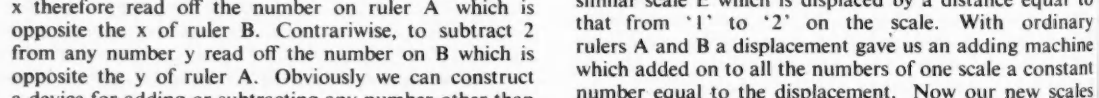
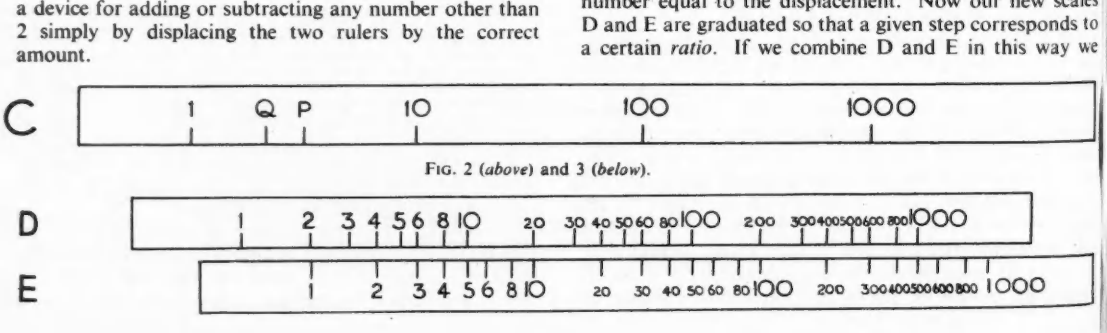


FIG. 2 (*above*) and 3 (*below*).



have produced a multiplying device. The distance '1' to '2' corresponds to the ratio 2 : 1 so if E is displaced by this amount each number on E will be exactly opposite a number twice as great on D, as can be seen is the case. In the example given we have multiplied by 2 but we could just as easily multiply by any other integer or, with a more finely graduated scale, by numbers like 2·56 and so on. What we have constructed is in fact the ordinary slide-rule which can multiply and divide and, by a slight complication of construction, can extract square and cube roots. With a good slide-rule an accuracy of three figures can easily be attained.

However, although a slide rule can do multiplication and division for us, there are plenty of quite simple jobs that it cannot do. A quite straightforward operation like striking the average of two numbers is quite beyond it. It is the sort of thing which can be done in the head so it does seem a bit pointless to make a diagram for it, but let us do it all the same. For this we need three ordinary scales L, M, N (Fig. 4) arranged parallel with M midway between the other two.

If we take a straight-edge and lay it through any number on L and another number on N it will cut M at the average of the two numbers. This is quite easy to prove, or trial and error will convince one of the truth of the result. This is an extremely simple example of what is called a 'nomogram'—a graphical device for solving a particular numerical problem. It may reasonably be asked whether the result obtained is worth the trouble, but we can very easily make this same nomogram solve a whole series of worth-while problems for us.

If one takes a spherical mirror of radius R and sets up a pin at distance u from the mirror the image of the pin will be formed at a distance v and the formula connecting the quantities is $\frac{1}{v} + \frac{1}{u} = \frac{2}{R}$

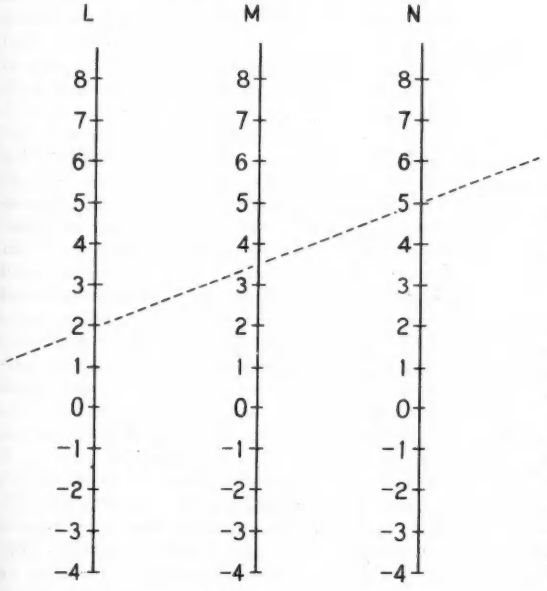


FIG. 4.

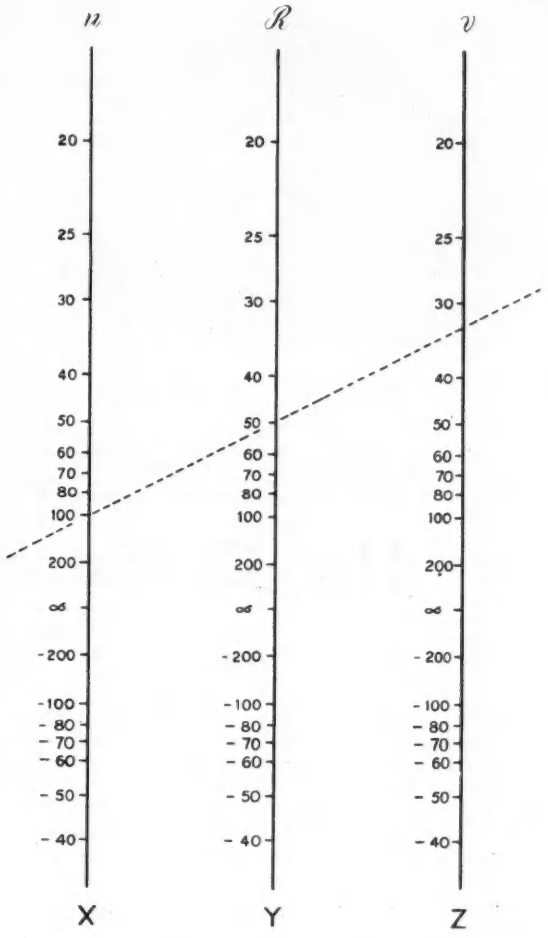


FIG. 5.

that is, the reciprocal of R is the average of the reciprocals of v and u. All that we have to do is to re-name all the marks on the scales L, M, and N with numbers which state, not the distance of the point from the zero mark, but the reciprocal of that distance. X, Y and Z are three scales (Fig. 5) marked in this way, and this nomogram will solve all the mirror problems that can ever be set in any school examination and with a slight change will do all the lens problems as well. The straight line drawn as an example shows that an object 100 cms. away from a mirror of radius 50 cms. produces an image at a distance of 33·3 cms.

These are but a few examples of what can be done with rulers. The last one is an introduction to a whole branch of mathematics called nomography—the technique of constructing diagrams to solve particular numerical problems. In many cases curved lines have to be used but almost all equations can be solved in this way. It is a study which has very important applications in engineering where large numbers of similar calculations may be needed in a particular type of work.

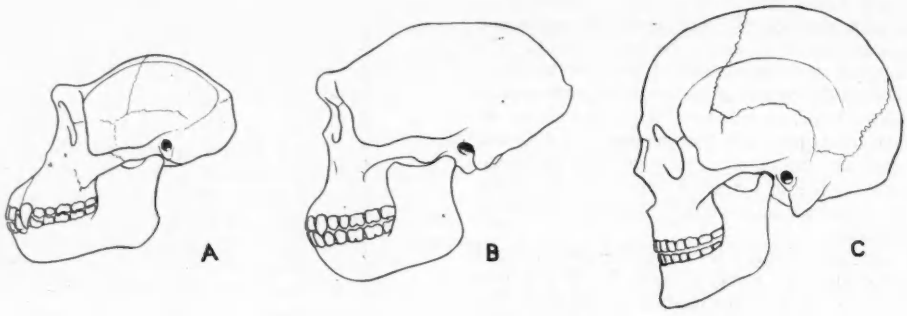


FIG. 1.—Side view of the skulls of (A) a chimpanzee, (B) *Pithecanthropus* (as restored by Dr. F. Weidenreich) and (C) a modern man. Each skull is represented at about one-fifth its natural size. Although the *Pithecanthropus* skull was restored from several fragments of the brain case and jaws, it may be accepted as substantially correct in its general proportions. Note that the fossil "ape-man" in the shape of his skull and jaws provides in many ways a remarkable link between chimpanzee and man.

The Oldest Human Fossils

PROFESSOR W. E. LE GROS CLARK, F.R.S.

OVER fifty years ago, a Dutch anthropologist named Dubois discovered in Central Java, buried in a river bank, portions of a skeleton which aroused acute discussion among students of human evolution. They consisted of a skull cap, a tiny fragment of the lower jaw, a thigh bone and some worn molar teeth. The skull cap might have belonged to a very primitive type of man, but it showed remarkable ape-like characters in its general flattened shape, its enormous eye-brow prominences, the complete absence of what is usually called a forehead, and its small size. On the other hand, the thigh bone, in its shape and proportions, was obviously adapted mechanically for the same kinds of stress and strain for which a modern human thigh bone is adapted; its owner evidently stood erect and walked much as we do to-day. The creature to whom these skeletal fragments belonged was called by its discoverer *Pithecanthropus*, or the "ape-man". Some anatomists believed it to be really a giant gibbon, others that it was a real man but of an exceedingly primitive type, and yet others saw in it the "missing link"—half-way between ape and man. The last interpretation seemed to accord with the size of the brain-case (which gives a close indication of the size of the actual brain). The capacity of the brain case of *Pithecanthropus* was estimated to be about 900 cubic centimetres, which is approximately intermediate between the average skull capacity of the largest living apes (about 500 cubic centimetres) and that of modern man (about 1350 cubic centimetres). Thus it appears that the brain of *Pithecanthropus* was intermediate between modern apes and modern man in point of size, even though it must be admitted that exceptionally small brains, corresponding to a cranial capacity of 1000 cubic centimetres or even less, do occasionally occur as normal variations in modern man.

Several hundred scientific papers have been written about Dubois's discovery since it was made, and for many years popular accounts of human evolution have always included a reference to the fossil "ape-man" of Java. Unfortunately, however, the remains of the skeleton are so scanty that the interpretations put on them have often led to a great deal of uncertain speculation. It is not generally known that during the last ten years or so new discoveries of the highest importance have been made in the Far East which have given us much more certain knowledge of *Pithecanthropus*. Indeed, we can now build up a fairly complete picture of this extinct creature.

In 1936, and during the three following years, further remains of *Pithecanthropus* came to light in Java. These were all the more unexpected because, since Dubois's discovery of the original remains in 1891, many unsuccessful attempts had been made to find further material; indeed, during 1907 and 1908 an expedition was dispatched to Java for this specific purpose, but intensive excavations failed to find anything of importance. The new discoveries now available for study comprise a large portion of a massive lower jaw with several of the teeth in position—an adult skull (much more complete than the original skull-cap) the back portion of another skull with a considerable part of the upper jaw and teeth, part of the roof of a third skull, and the skull of an infant. This last discovery, of a baby *Pithecanthropus*, is of the greatest interest. It was found at a place called Modjokerto in Central Java (not far from the site of the original discovery in 1891), and from its anatomical characters probably belonged to an infant of two years of age, or perhaps a little older. Compared with the skulls of modern children of an equivalent age it is small, for its cranial capacity is estima-

ted at about 700 cubic centimetres (in comparison with about 1000 cubic centimetres for a modern child of two years), and by reference to data concerning the brain growth of modern man and the anthropoid apes it may be inferred that the capacity would probably not have expanded beyond 1000 cubic centimetres in the adult. The brow ridges already at this early age are extraordinarily prominent, and the forehead region (which in apes as well as man is relatively more prominent in the infant than it is in the adult) is definitely retreating.

Let us now turn our attention to the Chinese village of Choukoutien, situated about 40 miles from Peking. In 1927 excavations carried out in caves at Choukoutien (under the direction of a Canadian anatomist, the late Professor Davidson Black) brought to light a single molar tooth of a primitive human type. The anatomical features of this tooth were deemed to be sufficiently distinctive to justify the inference that it must have belonged to an extinct type of man hitherto unknown, and to this type the name "*Sinanthropus*" (Man of China) was given. This conclusion met with a good deal of scepticism among anatomists generally, mainly because the sort of evidence provided by a single tooth seemed to be rather insecure. However, two years later other discoveries were made which vindicated the original contention of Davidson Black that the tooth was of quite an unusual character. Continued excavations led to the discovery, in 1929, of a fairly complete skull, together with portions of jaws and teeth. During the next few years (until the Japanese invasion of China stopped all further work) the remains of more skulls were found, as well as large numbers of teeth and some fragments of limb bones. Indeed, there are now available for study skulls, or portions of skulls, from Choukoutien of at least fourteen individuals, young and old, with teeth and fragments of jaws belonging to more than forty individuals, as well as the shafts of two thigh bones and an upper arm bone, a collar-bone and one of the bones of the wrist.

Both the Javanese and Chinese fossils have a great antiquity, geologically speaking. They probably date from the early Pleistocene age, and, in the case of some of the Javanese remains, perhaps even from the end of the preceding period, the Pliocene.[1]

It has already been mentioned that, when the Chinese fossils were first discovered, they were allocated to a special type of extinct man, *Sinanthropus*. However, comparative studies have now made it quite clear that they really represent the same type as the Javanese fossils, and it is therefore evident that they should both be included in the same *general* group (or genus), *Pithecanthropus*. At the same time they show certain differences of a relatively minor character which may be sufficient to indicate that they belonged to different species of extinct man. The original name given to the fossil man found by Dubois was *Pithecanthropus erectus*, to indicate that, as the evidence of the thigh bones seemed to show, the creature walked in an erect attitude like modern man. The Chinese fossils may therefore be distinguished by the name of *Pithecanthropus pekinensis*.

[1] For the information of those readers who may not be acquainted with the terminology of geological ages, it may be stated that the term Pleistocene is applied to the geological period immediately preceding that in which we now live. It was characterised in many parts of the world by a succession of ice ages during which great glaciers spread down from the polar regions and, in England, reached as far south as the Thames. There is evidence of an indirect nature that the Pleistocene period began at least half a million years ago.

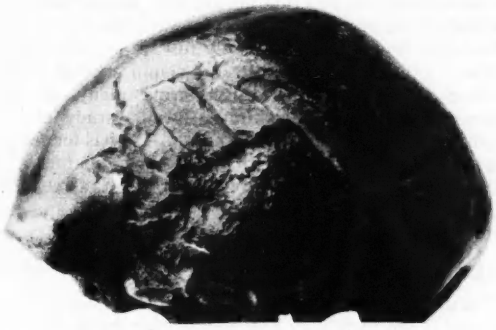


FIG. 2.—Profile photograph of a skull of a baby *Pithecanthropus* discovered in Java. × ½.

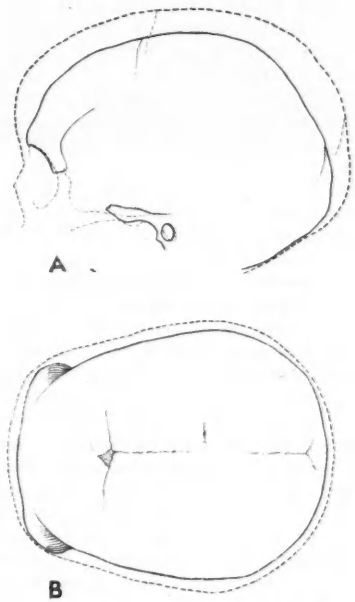


FIG. 3.—In these diagrams the outline of the baby *Pithecanthropus* skull (continuous line) has been superimposed on that of a modern child of three years (interrupted line). Note the retreating forehead and the large eye-brow ridges in the fossil skull. × ⅛. The side view of the skulls is shown in diagram A, and the top view in diagram B.

Since the death of Professor Davidson Black the systematic study of the Choukoutien fossils has been carried on by Dr. Weidenreich, and anthropologists are much indebted to him for the detailed reports which he has issued from time to time on his studies of the skeletal material. The recently discovered remains of *Pithecanthropus* in Java have been examined by a Dutch scientist, Dr. von Koenigswald, and short illustrated accounts of them have appeared,

but more extensive descriptions are still awaited and are not likely to be available till after the war. Meanwhile the information to hand is sufficiently full to permit a fairly confident opinion on the status and significance of *Pithecanthropus*. This information confirms many of the inferences which had been drawn from a study of the original Javanese fossil, but, on the whole, it has tended to emphasise the human rather than the simian character of *Pithecanthropus*. At the same time, as we shall see, this extinct type of man showed some very remarkable ape-like features.

A Low Intelligence

One unexpected result of the study of the *Pithecanthropus* material is the variability observed in their brain-size. In five of the Chinese skulls it was found to vary from 850 cubic centimetres to 1300 cubic centimetres (with an average of 1075 cubic centimetres), while in three of the Javanese skulls it ranges from 775 cubic centimetres to 900 cubic centimetres (with an average of 860 cubic centimetres). Thus the Javanese "ape-man" seems to have possessed a distinctly smaller brain and in this respect was clearly the more primitive of the two. The total average of all the *Pithecanthropus* material comes to approximately 1000 cubic centimetres as compared with 1350 cubic centimetres for modern human races. No doubt the small brain size is partly correlated with the fact that *Pithecanthropus* was rather an undersized individual by modern standards (his average height was probably not much more than five feet), but it cannot be altogether explained on this basis. For example, the average cranial capacity of the modern Bushman, whose average height is rather less than five feet, is about 1300 cubic centimetres. Since it is known that (apart from body-size) there is in modern man a statistical relationship between brain size and intelligence (though there are many *individual* exceptions), it may be inferred that the level of intelligence of *Pithecanthropus* must have been distinctly low as compared with *Homo sapiens*. It is interesting to note that a number of anatomists have attempted to learn more about the brain of *Pithecanthropus* by studying endocranial casts, as the casts of the inside of the skull are called. These give information on the shape and relative dimensions of the different parts of the brain, and also give faint indications of the pattern of the foldings, or convolutions, of the grey matter on the surface. Unfortunately, however, there is practically nothing which we can learn about the quality or the specific functions of the brain by this method. As regards general proportions, however, a glance at Fig. 4, which shows endocranial casts of *Pithecanthropus pekinensis* compared with those of a chimpanzee and a modern man, will make it clear that the fossil "ape-man" does occupy a position which is in many respects intermediate between the two others.

In association with the small size of the brain, the skull of *Pithecanthropus* shows many lowly chracters. The heavy and prominent eye-brow ridges first attract attention, and are strongly reminiscent of those found in the gorilla and chimpanzee. They are continued across the mid-line above the root of the nose to form a continuous projecting shelf, and in this respect (apart from their size) are quite different from the eye-brow ridges seen in modern man. The forehead region slopes gradually upwards and backwards from the eye-brow ridges, and only in the Peking skull is there developed in some cases a rounded prominence which can be properly termed a "forehead". The back of the skull is rather sharply pointed (instead of being evenly rounded as it is in *Homo sapiens*), and it has an extensive area for the attachment of what must have been very powerful neck muscles. As seen from behind the whole brain-case is flattened from above downwards, with its width greater than its height and its widest part at the base (as in the anthropoid apes). In modern man, on the other hand, the widest part of the brain-case is in the parietal region of the skull, that is, considerably above the level of the base, and, viewed from behind, its height is greater than its width (see Fig. 4).

The nose of *Pithecanthropus* is broad and flat, as it is in the lower races of mankind to-day. The jaws are massive, and markedly prognathous, projecting forwards, in muzzle-fashion, considerably beyond the level of the nose and the rest of the face. As in apes, also, there is no chin in the ordinary sense, for the front of the lower jaw retreats backwards from the level of the incisor teeth. In a number of points the teeth show simian features—their size, the massiveness of the canine tooth and its rather late appearance during the "cutting" of the teeth in the growing child, and some details of the pattern of the crowns. Yet, in spite of these primitive characters of the jaws and teeth, they are seen to be essentially human in general conformation when compared with these structures in modern apes. For example, the teeth are arranged in an even curve, whereas in modern apes the grinding teeth of either side are disposed in parallel, straight rows ending in front in the sharp projecting canines. Again, though the canines in *Pithecanthropus* in some cases are rather pointed and project beyond the level of the crowns of the other teeth (particularly in the Javanese representatives of this extinct race), they are approached in these characters by the canines of some modern individuals. Before the recent discoveries in the Far East, many anatomists had supposed that the dentition of *Pithecanthropus* must have been much more ape-like than it has now turned out to be; indeed, it was at first a little surprising to find that it approximates so closely to that of modern man. But a few years ago in India and South Africa remains of fossil anthropoid apes were unearthed in which the teeth are almost as human in their appearance. It seems certain, now, that in his evolutionary development *Homo sapiens* never passed through a stage in which the teeth were quite like those of the gorilla or chimpanzee of to-day. Indeed, the great pointed canines which give such a "brutish" appearance to these animals, and many other striking features of their dentition, are no doubt specialised side-lines of evolutionary development peculiar to themselves.

We have mentioned above that a few limb bones of *Pithecanthropus* have been found, though unfortunately they are few and fragmentary. Yet they are sufficient to demonstrate a rather remarkable feature. In spite of the primitive character of the skull, brain and teeth, the limbs seem to have been quite similar in their shape, proportions and fine modelling to those of present-day man. This at first appears surprising, since it seems to indicate that the limbs of prehistoric man reached their evolutionary termination long before the skull, brain and teeth did,

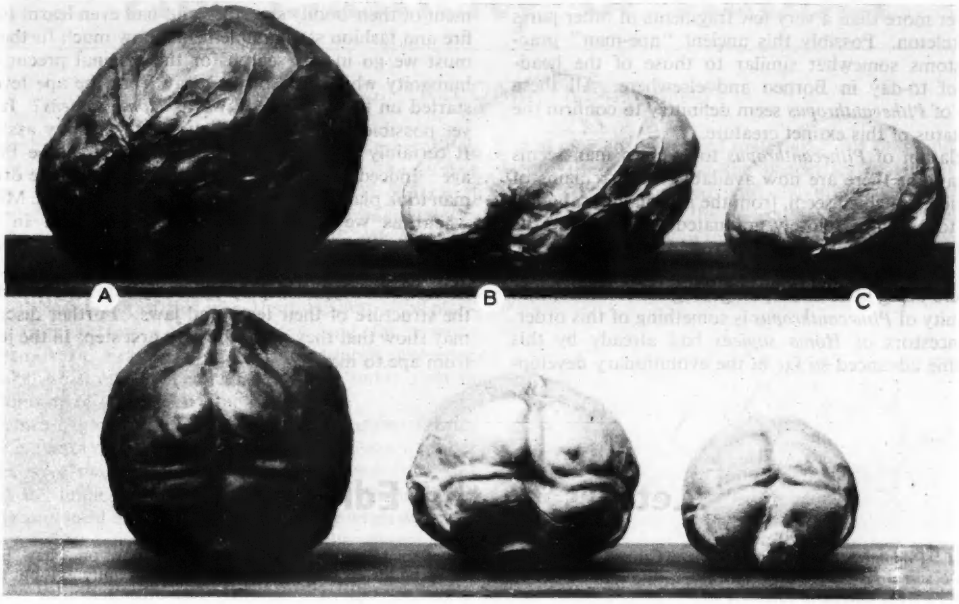


FIG. 4.—Photographs, from the side (*top row*) and back (*bottom row*), of the casts of the inside of the skull of (A) a modern man, (B) *Pithecanthropus pekinensis* and (C) a chimpanzee. The casts give an accurate idea of the size and shape of the brain. Note that, in its general proportions, the brain of *Pithecanthropus* occupies an approximately intermediate position between modern man and the chimpanzee. × $\frac{3}{16}$.

However, there are examples among other animals of such relative contrasts in the rapidity of the evolutionary growth of different parts of the body. For example, the fossil record has shown that in the lemurs (small animals which represent a lower grade of the mammalian group, the primates, to which monkeys, apes and man belong) the limbs acquired their final proportions long before the skull and brain. In relation to human evolution, the limb bones of *Pithecanthropus* are important for the consideration of the antiquity of man. For, if the characteristically human type of limb had already been perfected at the beginning of the Pleistocene age, the point in geological time at which the ancestors of man diverged in the course of evolutionary development from the precursors of the modern large apes must have been a good deal earlier than many anthropologists in the past have supposed.

A Missing Link

We may now consider the general bearing of the *Pithecanthropus* fossils on the problem of human evolution. In the first place, there seems nothing to preclude the assumption that this extinct type was really directly ancestral to modern man, for it seems to combine all the general characters which might be postulated for such an ancestor simply from a study of the comparative anatomy of the existing types of man and ape. But if *Pithecanthropus* had already achieved human status (even though far more primitive than *Homo sapiens*), where did he come from? It must be admitted that a gap in the fossil record still exists here. This gap, however, is gradually being closed. Mention has already been made of fossil apes from India and South Africa with some remarkably human characters. But these were definitely apes, and *Pithecanthropus* was definitely man. Between the fossil man-like apes and the fossil ape-like man there exists somewhere awaiting discovery the remains of a real intermediate "missing link". Even so, however, *Pithecanthropus* by itself, definitely constitutes a "missing link" since, as we have seen, it goes a very long way towards bridging the gap between *Homo sapiens* and his hypothetical simian ancestor. From this point of view, the fossil remains from Java and China provide a remarkable vindication of the Darwinian conception of the descent of man. From all the evidence at hand, it can now be confidently inferred that, even if the evolutionary ancestor of *Homo sapiens* lacked some of the characteristic features which are distinctive of the *existing* anthropoid apes, in its general anatomical make-up it came within the category of what zoologists call "anthropoid apes". So far we have considered *Pithecanthropus* simply as a zoological specimen. What can we say of his habits of life? So far as the Chinese representatives of this group are concerned, he was evidently able to fabricate stone implements of a primitive type, for these have been found in close association with his skeletal remains. He also knew how to make fire, for remains of hearths and chips of burnt animal bones have been discovered in the caves of Choukoutien. Further, it has been suggested that he practised cannibalism, since many of the skulls show signs of injury as though their owners had met with a violent death, and they are broken in a fashion which leads to the supposition that this was done in order to extract the brain. It is certainly a curious fact that, while a number of skulls, jaws and teeth have been found, the most careful excavation of the caves has failed

to discover more than a very few fragments of other parts of the skeleton. Possibly this ancient "ape-man" practised customs somewhat similar to those of the head-hunters of to-day in Borneo and elsewhere. All these activities of *Pithecanthropus* seem definitely to confirm the human status of this extinct creature.

The relation of *Pithecanthropus* to modern man seems fairly clear, for there are now available many remains of prehistoric man which seem, from the morphological point of view, to provide a closely graduated series linking the two. Thus there now exists no structural hiatus in the sequence of human evolution for the last half million years, there being little doubt, on geological evidence, that the antiquity of *Pithecanthropus* is something of this order. If the ancestors of *Homo sapiens* had already by this remote time advanced so far in the evolutionary development of their bodily structure and had even learnt to make fire and fashion stone implements, how much further back must we go in our search for the original precursors of humanity which first broke away from the ape level and started on their journey towards *Homo sapiens*? It is not yet possible to answer this question with any assurance. It certainly could not have been later than the Pliocene age. Indeed, the present indications are that the origin of man took place in a still earlier geological age, the Miocene, when (as we know from fossils discovered in India) primitive large apes of different types were undergoing their development in many divergent directions. Some of these extinct types display curiously human characters in the structure of their teeth and jaws. Further discoveries may show that they mark the very first steps in the journey from ape to man.

Letters to the Editor

A Critic of "Popular Science"

SIR,—Do scientists realise how harmful popularised science can be to them? I was disgusted to see a documentary film *Men of Science* at a News Theatre here, which so misconstrued the purpose and ideals of scientific research, as to give the impression that Faraday and Davy (whose work is pictured) were great, simply because aeroplanes, buses, wireless communication have resulted from their work. This is surely sufficient reason for the man-in-the-street to regard science as an unnecessary evil.

What should be done, in my opinion, is to make people realise the intrinsic value of science, the fact that it is an end in itself, in which genius and creative ability play just as important a part as in music, literature and art, and that its sole purpose is to find out how nature manifests itself. It should then be brought out that the aims of technology, or applied science, are very different, though of course no less important. There the underlying principle is to make life more comfortable, by making use of the facts discovered by the academician.

After all, we do hope that after the war larger sums will facilitate the expanding of research, and to that end the public must realise the meaning and value of science in the correct perspective.—Yours etc., HANNA LOEBL, The Women's Union, King's College, Newcastle-on-Tyne.

Scientists' Attitude towards Fleet Street

SIR,—As a person with a scientific training and many years experience in Fleet Street, I wonder if I may tell scientists a few things which in their aloofness they may not be aware of.

The attitude of the average scientist to the man-in-the-street seems to be a mixture of superciliousness and condescension in a "worship me if you will—I know I am a super-man" atmosphere.

Owing to the scientist's studied withdrawal from everyday affairs Mr. John Citizen, knowing nothing of scientists as human beings, is inclined to be afraid of him. Afraid, not of a person, but of something removed from his ordinary existence which has power to harm him. He fears scientists are hand in glove with employers in the latter's endeavour to save labour. He looks on the experimenter as a man who, divorced from human feelings, may evoke terrifying war machines without giving one thought to the purpose for which they may be used and the number of people they may kill.

There is perhaps also a little contempt that the scientist should be content to ask so small a wage when giving his brains to the service of interests who have no concern but the making of profits. Pity is felt, too, that the scientist should be so completely imprisoned in his own little world.

Assuming all these premises are incorrect what can be done by scientists to counteract this feeling?

In my opinion, one of the first things is for scientists and scientific institutions to be more approachable by the lay press and to be less secretive. There has been misquotation in the past, but it has not always been the fault of the journalist. If any scientist is purposely misquoted he can complain of this unethical conduct to the newspaper and to the National Union of Journalists. A journalist will not last long in Fleet Street if he consistently misquotes—for one thing it is liable to turn out too costly for his newspaper!

My own experience in dealing with scientists has been far from favourable. Sometimes there has been a polite refusal of comment or an authoritative opinion, but frequently there has been plain rudeness at my daring to ask for comment. There is a tendency, though, for biologists to be more favourably disposed towards the press, probably because they themselves have done a great deal to "popularise" their subject. This is reflected in the better knowledge the public has of some biologists. The public seems to have no horror that biologists may one day produce incredible plants or animals: but they do definitely fear other scientists, who, they think, may one day blow them all to pieces.

Even when willing to divulge information, scientists and scientific institutions seem to prefer the "safe"—i.e. right-wing—newspapers.

A certain famous society was due, some weeks ago, to announce the names of its new Fellows. I asked to be allowed to receive the list of names but was informed that only four favoured newspapers would receive it. I was ungraciously told that I could get the list from the news agencies. In other words there was discrimination against the "popular" press. It was true we could have got the names from the agencies—but hours after they had been issued, together with any errors that might have crept into the agency story and which could not have been checked. And for this the "popular" press would have been blamed again for its "inaccuracy".

The work of the scientist has such a powerful influence on public life that it cannot remain hidden from the public. The citizen has the right to demand that he should know what is going on in the scientific world. And it will not be good enough for the scientist to say "Here is something new, do what you like with it." The scientist, equally with the politician, is in the public eye, and he himself, as well as his work must be known to the man in the street. The scientist will have to come out of his shell and become known as a human being. He can no longer hide behind a facade of mystery.—Yours etc., —"A SCIENCE CORRESPONDENT".

(The identity of the writer of this letter is known to the Editor, who wishes to point out that he does not welcome anonymity in the correspondence column and will permit it only in special instances when he is satisfied that the correspondent's remarks are made in good faith and that publication above a name is out of the question).

The Elasticity of Rubber

L. R. G. TRELOAR, Ph.D., F.Inst.P.

RUBBER has become such a common feature of present-day existence, that it is difficult to realise that the rubber industry is not much more than 100 years old. In the last century practically the only source of the raw material was the wild rubber tree, *Hevea Braziliensis*, of South America, and it was only in 1910 that the first rubber from cultivated plantations of the same tree appeared on the market. Yet at the outbreak of this war, the total output of plantation rubber from Malaya, Ceylon and far eastern possessions of France and the Netherlands exceeded 1,000,000 tons, and rubber had become a major asset in the economy of the British Empire.

Macintosh gave us the first waterproof rubber fabrics from his factory in Glasgow in 1823. These early rubber articles were made of rubber in the raw state; besides having an unpleasant smell, they suffered through becoming very hard in cold weather and sticky when warmed. These troubles were soon overcome by the invention by Goodyear of the process of vulcanisation, in which rubber is chemically combined with a small proportion of sulphur, under the influence of heat. Crepe soling is now the only important survival of the use of rubber in the raw or unvulcanised state.

With the expansion of the rubber industry, and with the development of synthetic rubbers, begun by Germany during the last war (after pioneer work had been done in Britain; see DISCOVERY, December 1944, p. 370), the scientific study of both natural rubber and synthetic rubber-like materials has proceeded with increasing rapidity; nevertheless the science of rubber is still a comparatively recent growth. This is particularly true of the physics of rubber, dealing with such questions as elasticity, crystallisation, and the size of the molecule, with which this article is particularly concerned. Here the subject has developed almost beyond recognition during the last ten years.

The elasticity of rubber is a very remarkable phenomenon. Apart from rubbers, elasticity is normally associated with hard solids, such as steel, which are most frequently crystalline. The range over which a crystalline solid can be elastically (i.e. reversibly) extended is quite small, generally only about 1% of its original length, but the forces involved are comparatively high. The extension of a steel bar by 1%, for example, requires a force of 150 tons per square inch. The elastic properties of rubbers are entirely different in order of magnitude. The range of extensibility is some 800% of the original length, whilst the force required for a 1% extension is only about 3 lb. per square inch, that is, smaller by a factor of 100,000 compared with steel.

What is the cause of this enormous extensibility? Why does the rubber deform under the action of forces which would have no appreciable effect on an ordinary elastic solid?

The answer to these questions is now beginning to emerge clearly from the work scientists are doing in many parts of the world on the molecular composition of rubbers and chemically related materials. We find when we look into the matter that the properties of rubber are very intimately associated with the properties of the rubber molecule; in fact, the molecule is itself highly elastic, and it is this elasticity of the molecule which is conveyed to the rubber in bulk. We therefore begin by looking at the rubber molecule.

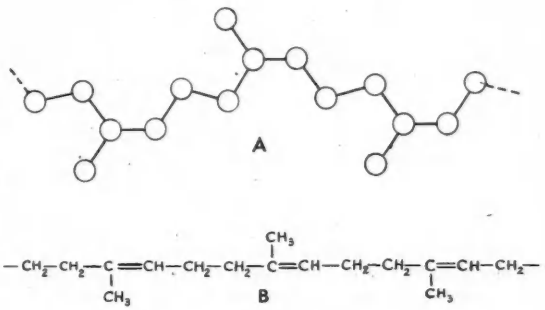


FIG. 1 (a).—Portion of rubber molecule, containing 3 isoprene units. The circles represent carbon atoms. (The hydrogen atoms are not shown).
(b).—Chemical formula for this system.

Apart from a small percentage of impurities, natural rubber is a definite chemical compound of carbon and hydrogen in the ratio of 5 atoms of carbon to 8 of hydrogen. The basic unit on which the molecule is built up is isoprene (C_5H_8), but the question of how many such units go into a single molecule, and how they are arranged has given rise to much controversy. It must be remembered that the science of chemistry has grown up on small molecules, having relatively few atoms each; when the number of atoms in the molecule is 1000 or more, the straightforward methods of the chemist are liable to give misleading results, or may break down completely. However, these difficulties have eventually been resolved and we now know that the isoprene units are joined together in a single line containing an average of 20,000 carbon atoms. Fig. 1 shows a short portion of the chain containing three isoprene units (the hydrogen atoms are omitted) and the corresponding structural formula. It is difficult to imagine the enormous length of the molecule; if magnified to a thickness of an inch, an average molecule would look like a rope about 500 feet long. The actual length is about one four-hundredth of a millimetre.

When we look at the chemistry of other materials possessing high elasticity, we find in all cases that the molecule is built up on the same general pattern, that is to say in the form of a very long chain. Generally the backbone of the chain is composed entirely of carbon atoms, but in some cases other atoms, such as sulphur or nitrogen, are present too. One cannot help being struck by the consistency of this general pattern underlying the wide diversity of detailed atomic constitution.

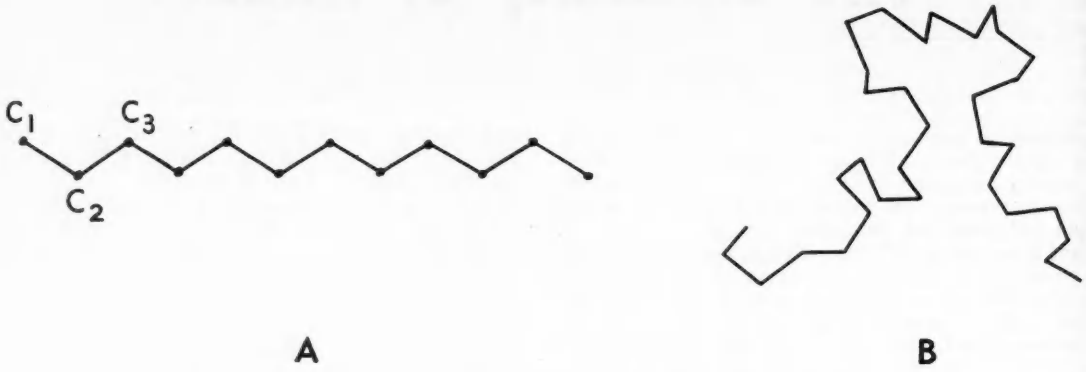


FIG. 2.—The form of a paraffin molecule, as it occurs (a) in the crystal, and (b) in solution.

It is this basic structural similarity which provides the clue to the understanding of rubber-like elasticity. About twelve years ago the idea began to germinate that the secret of the elasticity was to be sought in the *motion* of the atoms forming the molecular chain and not in the forces between atoms. This kinetic approach, first clearly enunciated by Meyer, v. Susich and Valko in 1932, proved very fruitful, and was rapidly developed in the succeeding years by several workers, notably by Kuhn, who showed that the elasticity of a chain-like molecule should increase with the chain length.

In discussing this theory the detailed structure of the chain is of no significance, so we take the simplest possible chain, represented by the paraffin molecule. The geometry of the paraffin chain is shown in Fig. 2a; C_1, C_2, C_3, etc represent the carbon atoms, which are joined by bonds of equal length. Adjacent bonds always make the same angle with each other ($109\frac{1}{2}°$).

We now come to the essential point of the theory. We know that the atoms in all matter are in a state of continual motion, this motion becoming increasingly energetic with increasing temperature. The type of motion varies with the restraints imposed by neighbouring atoms. In gases, the atoms move in a series of straight lines interrutped by occasional collisions; in solids they move in a vibratory manner, without changing their relative positions; in liquids the atomic motion is mainly vibratory, but with occasional jumps to new positions. The movement of the atoms in the paraffin molecule will be one of rotation in such a way that the essential constraints—fixed distance between atoms, fixed angle between bonds—are not violated. In other words, the motion may be described as the rotation of any given bond about an adjacent bond as axis. It is easy to see that the effect of these random rotations will be that the chain molecule will not lie in a single plane as depicted in Fig. 2a, but will assume an irregularly kinked three-dimensional form, as indicated in Fig. 2b. In this kinked-up state the distance between the ends of the chain is obviously less than the length of the planar zig-zag of Fig. 2a.

In long chains the shape produced by random rotations of the links between the carbon atoms is very complex. To illustrate this I have constructed a wire model of a 1000-link paraffin chain (Fig. 3), in which the position of each link was determined by the throw of a die, so as to simulate purely random rotation. The distance between the ends of this "molecule" (shown joined by a straight wire) came out at about 9 inches. The outstretched length of the same chain would be about 14 feet, which illustrates the enormous potential extensibility of the molecule.

Of course, the exact shape, and the distance between the ends is entirely a matter of chance. I might have thrown a 3 on the die 1000 times in succession, in which case the molecule would have taken the form of a straight chain, as in Fig. 2a. But the chance of this happening is 10^{778} to 1 against—in other words, it is a practical impossibility. On the other hand, the chance of getting a form of the same *general* character as that in Fig. 3 is very high. The mathematical analysis of the problem by Kuhn enables us to state precisely the probability of any given distance between the ends of the chain, for a chain having a given number of links. The curve of Fig. 4, representing his result, shows that the probability has a maximum for an end-separation which is very much less than the outstretched length of the chain.

Molecular Basis of Elasticity

We are now in a position to comprehend the nature of the elasticity of the rubber molecule, which differs in detail from the paraffin molecule. We note, for instance, that there are two types of bonding between the carbon atoms, the single bond (as in paraffin) and the double bond. The double bond represents a closer type of binding, in which the interatomic distance is smaller. Moreover, the double bond does not permit of the freedom of rotation which we have discussed in connection with the single bond. The rotatable units are thus rather different, but this does not affect the essential argument, and we are entitled to assume the same type of random kinking as has been deduced for the paraffin chain. The basis of the elasticity of the rubber molecule therefore is the same. If it is forcibly extended it is in a very improbable state; hence when the applied force is removed, the random thermal motion will quickly restore it to a more probable, (i.e. shorter) condition. Kuhn has shown that the most probable distance between the ends is proportional to the square root of the number of chain links. The outstretched length is of course proportional directly to the

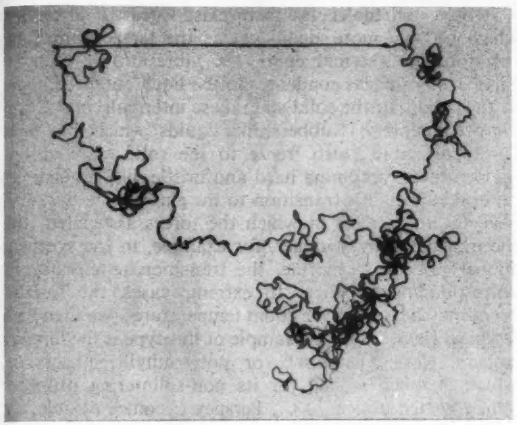


FIG. 3.—Model of paraffin molecule of 1000 carbon atoms, as it would appear if isolated. The rubber molecule is much longer than this, containing about 15,000 rotatable "links".

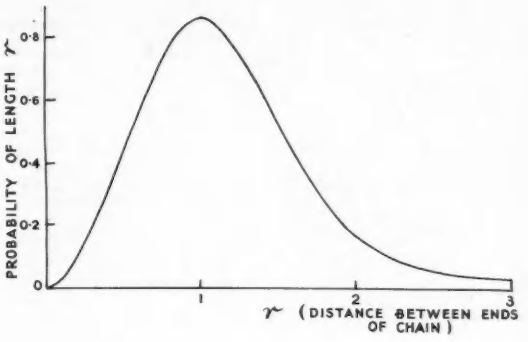


FIG. 4.—Curve showing the probability of a given distance between the ends of a randomly-kinked chain having a fixed number of links.

number of links, hence the *extensibility* is also proportional to the square root of the number of links—multiplication of the number of links by four doubles the extensibility, etc. The fact that rubber-like properties occur only in association with extremely long molecules is thus seen to arise as a perfectly natural result of the kinetic theory.

In the foregoing discussion our attention has been confined to the properties of a single isolated molecule, and we have seen how its elasticity arises quite naturally from the essential features of its construction. But it does not necessarily follow that the potential elasticity of the individual molecule will impart rubber-like elasticity to the material in bulk. To decide this it will be necessary to take account of the manner in which the molecules are associated, the forces between them, and so on. These points will be considered later. At this stage it will be sufficient to note that not all long-chain materials exhibit elasticity in bulk, and even in rubbers, the elastic properties only appear within a limited range of temperature. From the fuller development of the kinetic theory a number of conclusions may be drawn concerning the physical behaviour of rubber, which by comparison with experiment enable the validity of the theory to be tested. The most important of these are the following:

(1) The tension on a piece of stretched rubber held at a constant extension should increase proportionately with the absolute temperature. This conclusion is the direct result of the thermal or kinetic origin of the elasticity. As the energy of atomic vibrations and rotations increases with temperature, so does the resultant tension due to this motion. This question was first investigated experimentally by Meyer (one of the originators of the theory) and his collaborator Ferri in 1935. The theoretical prediction was exactly borne out by a well-vulcanised rubber over a temperature range of more than 100°C. In this recpect rubbers behave in the opposite way to ordinary solids.

(2) In stretching rubber there should be an evolution of heat, and on retraction heat should be absorbed. This property of rubber has been well established for a long time, but its significance has only recently been appreciated. In this, and in the preceding property, there is a close analogy between rubber elasticity and gas elasticity.

The first effect may be compared with the proportionality between pressure (i.e. the elastic reaction) and temperature in a quantity of gas maintained at constant volume, and the second with the familiar heating of a gas by compression.

(3) The third important set of conclusions is concerned with the stress-strain relations for rubber. Assuming vulcanised rubber to be a network of interconnected molecules (this is discussed below) it is possible to deduce theoretical relations connecting the applied force with the amount of deformation, under various types of strain, such as elongation and shear. The law of Hooke—that stress is proportional to strain—lies at the basis of the accepted theory of elasticity as applied to ordinary solids. The fact that in rubber this law is not obeyed, there being a pronounced curvature in the stress-strain curve of rubber in elongation, had given rise to much discussion but had never been satisfactorily accounted for until 1942, when Wall, of the University of Illinois, derived exactly this type of curvature on the basis of the kinetic theory. The predictions of the theory with regard to other and more complex types of deformation have also been strikingly confirmed by recent experimental investigations.

Let us now return to the question of the structure of rubber, and of other high-molecular substances in bulk, and see whether we can trace a connection between the variations in their elastic and other physical properties and their molecular constitution.

The Effect of Vulcanisation

We have to think of the molecules of raw rubber as continually "wriggling", each having a loose irregular form, yet at the same time closely intertwined with its neighbours, so that the whole space is densely and uniformly filled. The most helpful analogy to my mind is that of a bath of snakes (very long snakes, say, 500 feet long and an inch across), all wriggling about and mixed up together. If you get hold of one of the snakes and pull, it does not

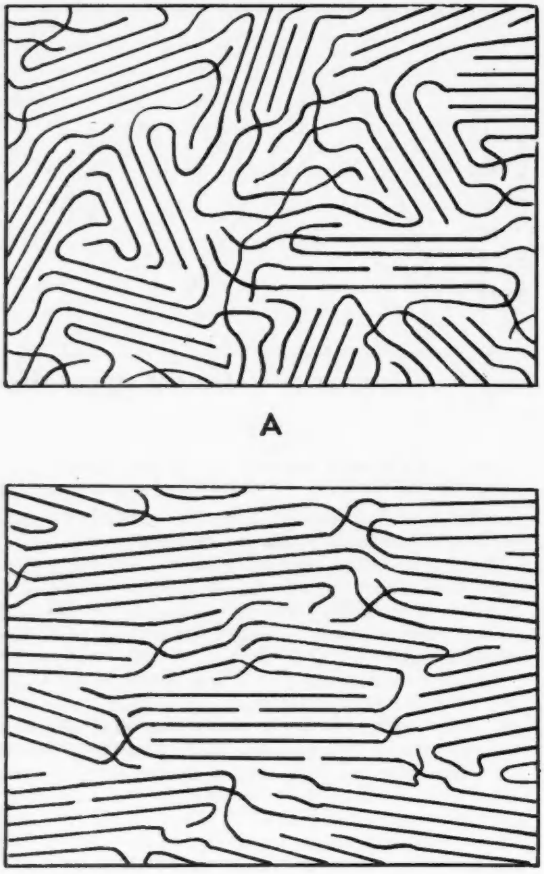


FIG. 5.—Diagram representing the molecular structure of crystalline rubber (a) unstretched and (b) stretched before crystallising. The parallel bundles represent crystallites.

come away immediately, but pulls its neighbours out of place. Only slowly does the snake which is being pulled manage to wriggle out, bit by bit. In the same way, raw rubber, when subjected to a force for a long time, gradually flows, i.e. it is plastic. The higher the temperature, the more readily does flow take place. This property of plasticity is of the utmost importance in the rubber industry, since it allows rubber to be shaped by extrusion, rolling, moulding, and so on before vulcanisation, which finally fixes the shape in a more permanent manner. Vulcanisation is a chemical process in which a small proportion of sulphur effects a cross-linking of the molecules. It is as though our snakes had each become joined to their neighbours at two or more points along their length. Locally the mass looks and feels much the same as before, but any permanent distortion or removal of one member from contact with its immediate neighbours is impossible. Vulcanised rubber is therefore more perfectly elastic than raw rubber, and is not plastic.

Between all molecules there exist forces of attraction which become more significant as the temperature (and therefore the thermal energy of vibration) is reduced. That is why the gas condenses to the liquid, and the liquid to the solid. In the solid state these intermolecular forces are predominant. Rubbers, like liquids (which they most nearly resemble), also freeze to the solid state at low temperatures, becoming hard and brittle, like a glass. In natural rubber this transition to the glassy state occurs at −70°C. In rubbers in which the forces associated with the molecules are stronger, for example, in the synthetic rubber polyvinyl chloride, the transition temperature is correspondingly higher. In extreme cases, the freezing point may be well above room temperature; we then have a typical glass. A good example of this type is the familiar organic glass "Perspex", or polymethyl methacrylate, which is much valued for its non-splintering property. When heated above 70°C., Perspex becomes flexible and ultimately rubberlike. The same applies to a number of other plastics (e.g. cellulose acetate), and this property is extensively utilised in industry for the production of shaped articles from sheet or tube.

As we have seen, the solidification to a glass, whether of a liquid or a rubber, takes place by the setting of the molecules in the positions which they occupied instantaneously in the liquid or rubber-like state. But the glassy state is not the commonest type of solid structure; most liquids prefer to solidify to the crystalline form. The crystalline state is characterised by a regularity of molecular arrangement not found in the liquid or glassy states; a certain geometrical pattern of arrangement of the constituent molecules or atoms is exactly repeated throughout the structure. The crystal thus resembles a regular three-dimensional lattice. Our knowledge of these facts has been obtained through the medium of X-rays. The pattern produced when a narrow beam of X-rays is fired through a liquid consists of an ill-defined ring or halo, indicative only of a certain average spacing between atoms. Exactly the same pattern is obtained from a glass. But a crystal yields a quite different pattern, a beautifully arranged array of spots of varying intensity, which could obviously only be produced by a perfectly regular disposition of the constituent atoms, or primary scattering units. The elucidation of the structures responsible for these unique patterns provides a fascinating story, to which the work of the late Sir William Bragg has largely contributed.

If natural rubber is held for several days at a low temperature, about the freezing point of water, it becomes opaque and comparatively hard. It is still somewhat flexible, but can no longer be stretched to any extent. In this condition, X-rays show us that it is crystalline. Some of the synthetic rubbers also become crystalline at low temperatures, but only those whose chain structures are themselves perfectly regular. The crystalline state of a rubber is quite distinct from the glassy state; unlike the latter, the transformation to the crystalline state is a slow process, taking several days at 0°C. A crystalline rubber is not brittle like most crystalline solids. It still retains some of its elasticity. This is because the crystallisation is never complete, there being always a proportion (perhaps 20 to 40%) of uncrystallised matter. We can see that this must be so. In the process of crystallisation each little

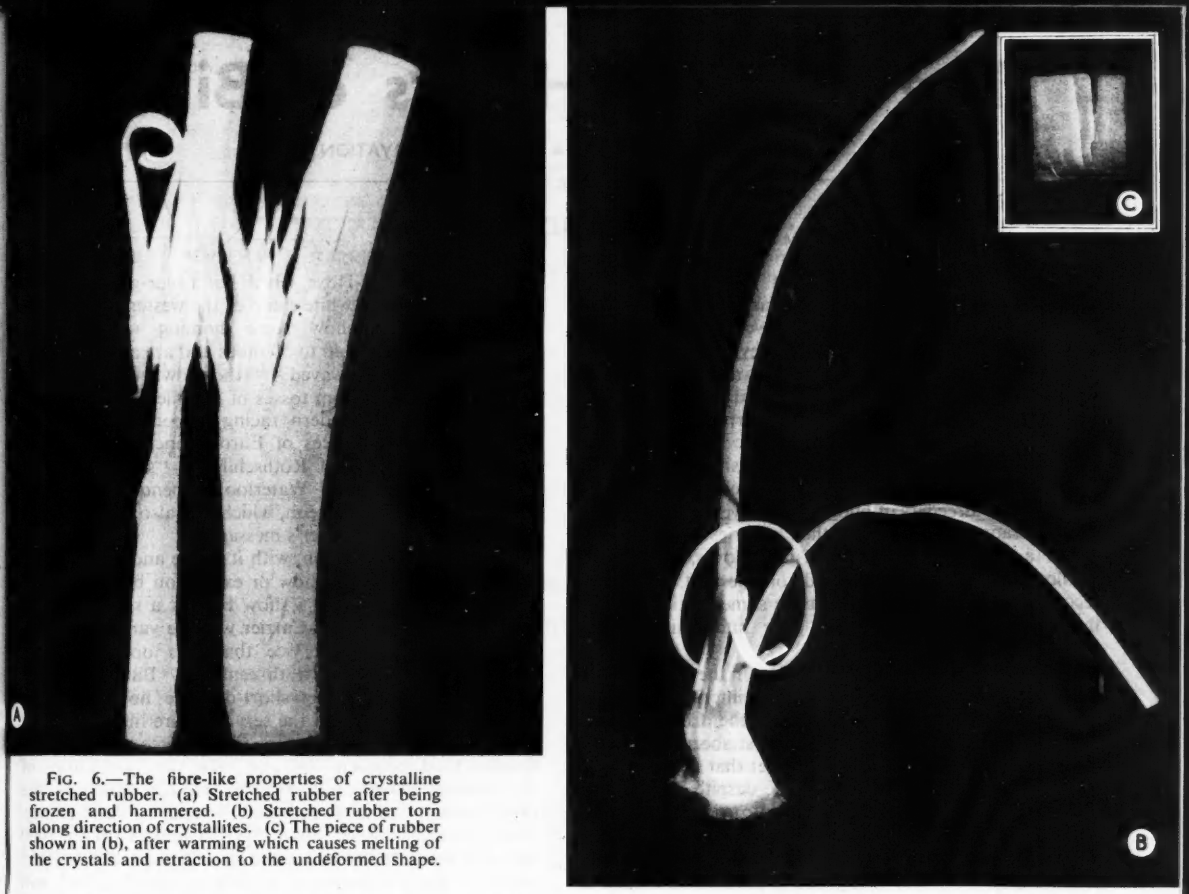


FIG. 6.—The fibre-like properties of crystalline stretched rubber. (a) Stretched rubber after being frozen and hammered. (b) Stretched rubber torn along direction of crystallites. (c) The piece of rubber shown in (b), after warming which causes melting of the crystals and retraction to the undeformed shape.

crystallite grows by attracting to itself portions of neighbouring molecules, which become arranged in the form of a bundle of parallel chains. Between the crystallites there are bound to be portions of molecules which are so hopelessly entangled that they cannot be fitted into any of the growing lattices; these portions remain uncrystallised. We have therefore in crystalline rubber a very peculiar state in which the crystals are embedded in and bound together by an amorphous network of long molecules. (Fig. 5a).

Polyethylene, which is simply a long-chain paraffin, is a good example of a crystalline rubber. In appearance it is similar to paraffin wax, yet on account of its amorphous-crystalline structure it is not brittle, like paraffin wax, but flexible, yet sufficiently hard to maintain its shape without vulcanisation. Since it retains the excellent electrical insulating properties of paraffin wax, it is an ideal substance for use as a dielectric in high-frequency cables.

Rubber, both raw and vulcanised, possesses the curious property of crystallising when stretched even at room temperature, where it does not crystallise in the unstretched condition. This remarkable effect, revealed to us by X-rays, becomes readily intelligible in terms of the molecular picture of rubber which we have developed. For, on extension, the molecules are partially straightened out and thus brought into more favourable relative positions for crystallisation. This will be clear from Fig. 5b. On releasing the tension, two effects may occur. In vulcanised rubber the crystals collapse, and retraction to the original length occurs, whilst in raw rubber, if the extension is high enough, the crystals remain and the rubber remains outstretched until heated to a sufficient temperature to cause melting of the crystals.

The parallel alignment of the crystallites in stretched crystalline rubber imparts to it a sort of fibrous texture which gives it properties rather like those of the well-known textile fibres. If rubber in this state is frozen in liquid air and hammered, it breaks along the grain in the same sort of way as a piece of wood (Fig. 6). Also, stretched crystalline rubber may be torn quite easily along the grain (Fig. 6b). If vulcanised in the stretched state (by a cold process) the crystalline condition is rendered permanent, and the result is a tough, relatively inextensible fibre.

From this account we see that the rubbers fall into a class of their own, structurally related to the organic glasses on the one hand, and crystalline and fibrous materials on the other. Many natural tissues have a molecular structure not unlike that of rubber. This is particularly true of muscle fibre, which is responsible for the elasticity and toughness of the animal body. Yet it is a curious reflection that very little is known of the chemical processes involved in the manufacture of rubber by the tree (indeed, a rubber having the exact constitution ofnatural rubber has not yet been synthesised).

The Homing Habits of Birds

THE RACING PIGEON AS A BASIS OF OBSERVATION

ERIC HARDY, F.Z.S.

AMONG birds, the homing instinct is not confined to pigeons. When garden blue tits, marked with coloured celluloid leg-rings, were removed several parishes away from a garden bird-table "trap" they were caught repeatedly in the original trap. Shearwaters taken from their nesting isles off South Wales and liberated in the Mersey estuary and in the Adriatic returned home, as did a storm petrel liberated in the Atlantic several hundred miles from its quarters off the Scottish isles. Nesting house martins taken from Croydon to Berlin behaved in a similar way. Breeders of budgerigars have had these small grass-parraquets "home" to their aviaries from releases up to a few miles distance. Turtle doves, as well as swallows "ringed" as adult birds on the nest, have been recovered and liberated again at the same nesting site for five and seven years, despite their intervening winter journeys to Africa.

More interesting still is the recovery, in the same wintering locality in England in successive winters, of starlings that in between times journeyed to the Continent for nesting. The homing habits of the lost sheepdog, or the pony whose rider is injured, the limpet that returns to the same roosting nitch at each low-tide despite its high-tide wanderings, and the snail that comes to roost regularly at the same stone are further examples of this sense of orientation.

During this war, after bombed-out people had moved to new lodgings frequently the family cat was reported lost, only to be discovered at the old home to which it had returned by instinct. The salmon that has been marked as a grilse as on its way down river to the sea almost always is found to return to the river of its birth, although salmon ova taken from the Scottish Solway and introduced to the Welsh Dee produced grilse which, after marking, returned to the Dee, the river of their upbringing—and not to the Solway, the home of their ancestors.

When some pigeons were to be sent from the Isle of Wight for liberation 200 miles north in England a wild wood pigeon on a nest near the loft was caught, marked by white-washing its tail, and put in the basket for liberation with the other birds; watchers reported its return about fifth in the race order.

Are these all examples of a similar homing instinct? The most suitable material for the observation and study of homing is the modern long-distance racing pigeon, so often misnamed the "carrier" pigeon or the "homing" pigeon, names which more correctly apply to exhibition varieties of pigeon that played their part in the past in the breeding of the modern racing pigeon, but in which the homing instinct never reached the perfection of achievement shown by the last-named bird.

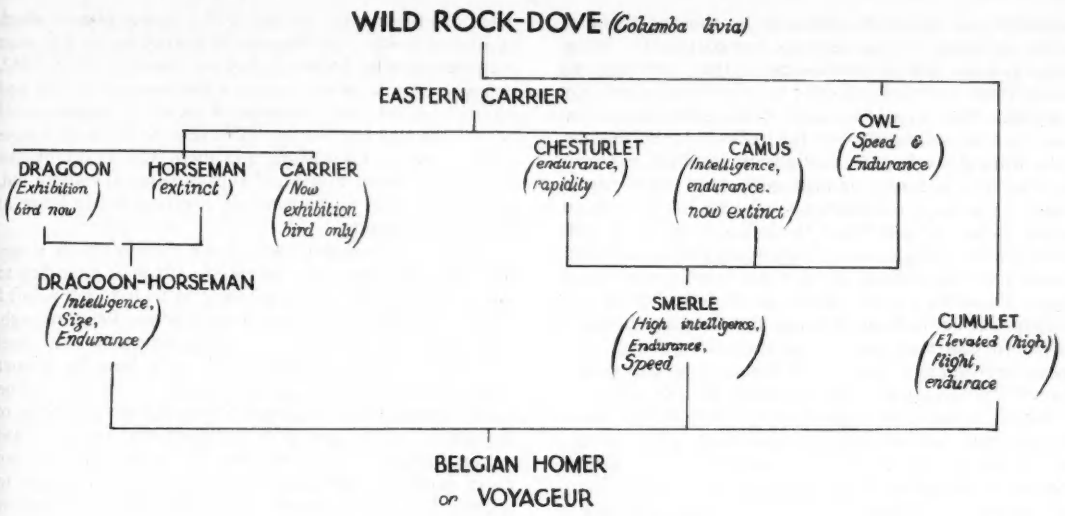
Domestic pigeons are descended from the Wild Rock-Dove of the sea cliffs (*Columba livia*) which, however, is largely static in its habits and shows no great migrations. (The ultimate origin of the domestic pigeon was probably in the Eastern Rock-Dove, which has a blue-grey croup or rump in place of the white rump of the western race). All domestic pigeons show some homing instinct. The Italian Modenas race 40 to 50 miles and are attracted into their lofts by flags waved by their owners. Even the Tumbler will home from tosses of 20 miles and, until the Belgians bred the modern racing pigeon, most of the "carrier pigeon" services of Europe (including the one that gave the House of Rothschild its "scoop" on the news of the Battle of Waterloo) depended upon the "Dragoon" breed of pigeon, which was also the kind that carried the original Reuter's messages.

The true Carrier-Pigeon, with its large and ugly wattles and cere, is now but a show or exhibition bird while the Homer Pigeon is mostly a show bird or a short-distance homer. The old Eastern Carrier was the variety used for the extensive pigeon service that was operated from Bagdad in the 12th and 13th centuries. But these early fliers were comparatively short-distance homers, doing only up to 50 miles, and the services were maintained by relays of birds. By crossing the various breeds the Belgian fanciers bred, between 1840 and 1850, the foundations of the famous 200-400 mile Belgian Homer which is the direct ancestor of all British and American modern long-distance racers, which home from distances up to 1000 miles or more over continental conditions (such as they meet in North America and India) or to England and Scotland from places as far off as San Sebastian and Barcelona in Spain, or to Belgium from Madrid, Algiers or Rome. The ancestry of the modern racer is based largely on the family tree shown in the diagram, the selected qualities of the various pigeon breeds being noted.

By careful selection based upon definite race results, and not without considerable inbreeding and crossing with the English Dragoon, the modern long-distance racing pigeon was bred from the Belgian Homer, mainly by the men of Verviers, Liege and Brussels. Several well-known strains of Belgian and Anglo-Belgian racing pigeons are recognised, such as Stassarts, Bricoux, Gits, Wegge, Gurnay, Logans, Osmans and Barkers, the strains taking the name of the breeder who originated them.

These introductory remarks on the origin of the racing pigeon are necessary to appreciate that its homing abilities were bred by careful selection from latent abilities in an ancestor, the Wild Rock-Dove, which is mainly residential in one district during its natural life.

Several theories as to the stimulus of the homing instinct in pigeons have been published by biologists and experts on pigeon racing. One that has received much publicity on the Continent is that the homing bird is sensitive to a magnetic influence or to the radiation of radio waves. This does not stand up to practical experiment, however, for pigeons released in the vicinity of the greatest possible magnetic influence engineers can produce show no noticeable difference in their abilities; nor have pigeons been



THE ANCESTRY OF THE HOMING PIGEON.

affected though released near Droitwich, with the station transmitting at varying frequencies and with a wide range of power output. R.A.F. pigeons have homed from bombers to lofts at airfields where powerful high-frequency wireless transmitters are constantly working, and Army pigeons have operated in France over areas where there have been thousands of transmitters sending out carrier-waves over ranges of a thousand yards to 100 miles or more. Apart from the effects of physical fatigue and extremely bad weather, which do not so much nullify the functioning of the homing instinct as put physical barriers in the pigeon's way, the only things which I have found to blot out the instinct in pigeons are dense fog, the blast of bombs and mental injury (such as hæmorrhage). The instinct is also upset by frequent moving between places without letting the birds see their surroundings or "settling" them to the new positions in such a way that the birds have no memory of any loft or site to which they can home. Sultry weather before a thunder storm reduces homing efficiency.

Sight and Memory

The homing abilities of pigeons are based mainly upon sight and memory. It is the lack of visibility which prevents their homing through fog, although pigeons will come in through light fog, ground fog and ground mists, and over vast stretches of water where there are no guide marks. The fact that they use the coasts in their travels, as do the migrant wild birds, is probably explained not so much by the need of sighting landmarks as by their inherent fear of the sea. They likewise avoid crossing great mountains, and it was the Alps, as much as the weather, that caused the disastrous "smash" in the 1000-mile race to Britain from Rome several years before the war. American and Australian racing pigeons fly much longer distances than do British birds because they have continental conditions, and encounter stretches of land that unbroken for 1000 miles or more and are without any serious water barrier comparable to the English Channel. Birds in the English races from Lerwick (in the Shetlands) and Thurso and Banff in North Scotland do not cross the Highlands but come down via the coast, as the recovery of strays proves. For this reason the old Midland Homer League adopted the training stages for these race birds from points as between Newcastle, Berwick, Arbroath and Banff—all coast towns. It is notorious that pigeons will not home across Morecambe Bay but make the longer journey round its edge, and birds flying from Spain to lofts in S.E. England appear to skirt the north coast of France and cross the narrow Straits of Dover. Birds flying to England from France and Spain are always shy of crossing the Channel, especially in foggy weather, and sometimes hundreds of pigeons which have refused to negotiate it may be seen in the Channel Islands. However, pigeons will home 60 miles and more from ships or 'planes at sea to land lofts and they can be trained to fly to ships. Wind has only a physical effect, although birds sometimes home better against the wind than with it, and I have known a cross wind blow them off their loft site so that they overshoot it and come in from the opposite direction of the race point.

Early in the war, my wife and I ran a NARPAC first-aid post for animals in Liverpool and during the blitz I frequently found pigeons (and dogs) quite unharmed physically, but mentally they had lost all sense of home direction. The pigeons would stay about until some mental stimulus brought back the instinct—for instance, the sight of other pigeons flying by. Normally stray pigeons from the big races often drop exhausted into a strange loft, but after being fed or watered back to strength and fitness, they return to their home loft when liberated.

The homing instinct of pigeons seems to originate in the "territory right" of the nesting season, a sense of home territory shown by most birds and very conspicuous with the garden redbreast. Where several pairs of pigeons are bred in a large loft with about a score of nesting com-

partments, the birds are paired-up by shutting them up awhile in their allotted nest-box compartments. When released, each pair of birds stick to their own original compartment and they will drive out with furious peckings any pigeon that dares to intrude. I have seen pigeons that have been away from the loft for weeks, or even months, make straight for their old nesting compartment and drive out the new occupant immediately upon their return. Likewise they gain a territory sense for the loft as a whole, for the garden or field where the loft is built, and for the hill-side or wood-side or river-side where the place is sited. From birth this territory sense is firmly implanted in the pigeon's mind by what it sees around it, and when sending birds to races or to home distance, their baskets should be so placed that they cannot see the surroundings. This keeps the memory of their home stronger, and they cannot develop the site-memory for any temporary home.

The pigeon-racer uses stimulants to the homing instinct, ranging from racing birds at various stages of breeding—to add the eagerness to return to eggs, to a mate or to its young—to the extreme of using patent energy pills or peas soaked in whisky, beer or sherry! But pigeons of either sex will home at all ages and at all times of the year; they will home by day or night, in good weather or bad, and to lofts so well camouflaged that they are overlooked by human observation from the air. The birds can be moved to a new loft or the loft moved to a new position any distance away and providing the birds are properly "settled" to that new loft they will home to it from a long distance because the "settling", with the visual experiences it involves, has given them a fixed memory of the new site strong enough to make them forget the old one. They can be "settled" to new sites repeatedly, adaptation not being restricted to a single change of location. But if they are not properly "settled" they will return to the original loft or locality.

They do not have to be breeding in the loft to be "settled" to it. However, they cannot home to a loft that has been moved far during their absence, because then they have no visual memory of its new site, although they will home to one that has been moved during their absence providing it is still within sufficiently short range for them to find and recognise it during their reconnaissance round the vicinity after they fail to find it in its original position. Pigeons can also be "settled" to ships (i.e. lofts on the decks of ships) or small boats, and they will home to that ship when released some distance away, recognising the particular vessel among several scattered over a harbour or a bay; but each time their ship moves they have to be "settled" again to the new site before they can be flown successfully to it from a distance. Feeding-in to a loft is an important aid to settling. By feeding it at one place and watering at another a pigeon can be "settled" to two different loft sites at the same time so that it will home to each in turn.

The memory of pigeons for their original loft-site is considerable, and becomes evident when storm-exhausted strays are stolen by unscrupulous fanciers or when birds sold to new owners are not properly settled. Here is one example. In November 1943, a pigeon fancier in Akron, Ohio, gave some pigeons to the U.S. Army who sent them to Claiborne. In June 1944 one of these birds escaped from Army lofts and returned home, a distance of 1125 miles. Another instance: in 1927 a racing pigeon which had twice flown from Rennes in France to its loft near Manchester failed to home, but on Christmas Day 1932, its owner was surprised to find it had entered the loft and was fighting with other inmates of the loft to regain its old perch; the bird had not taken five years to fly the 300 miles from France to Lancashire, and there was no doubt that it must have been stolen and kept prisoner elsewhere but, not being settled to the new site, it proceeded to home at its first opportunity.

It is true that pigeon racers train their birds by stages over the route they are to be raced. If I were intending to race birds from Berwick-on-Tweed to their London loft I would train them by stages from Hitchin, Peterborough, York and Newcastle before "lifting" them to their final race point at Berwick. But this is only done for greater perfection, because very young pigeons, which have had no such training, have the ability to home from all points of the compass; they seem to be born with that ability. I had the experience of a two months-old pigeon that had not flown more than 1000 yards to its loft being sent by mail to another loft nearly 50 miles away and before it could be settled there it escaped and returned to us. A well-known Preston (Lancs.) pigeon flew the 400 miles from Rennes at the age of 19 weeks, and another bird flew 548 miles from Marennes to Preston when 23 weeks old. It does not require much experience of racing pigeons, however, to notice how individual birds vary in their intelligence, and some birds are capable of being settled to a new loft quicker than others and become capable of homing sooner.

In the training of young birds all pigeon racers experience losses or strays which are not due to bad weather but to a mentality that is dull in homing sense. It is much easier for a basket or pigeons to make a long-distance flight home when released as a pack—for they will "pack" and the dull ones make home at the guidance of the clever ones—than to toss them singly at intervals from the race point, waiting for each to clear before the next is put up, when they have to make home on their own wits. A dull bird flying singly will often attach itself to a passing flock of pigeons homing to some other town (this happens especially when the odd bird is a youngster or a yearling) and thus go astray. I used to visit a publican's loft two miles north of Leigh-on-Sea; he described how, when he entered a couple of birds in a race from York they were released along with 50 or more birds from the rest of the Leigh Club, most of the pack flew together and his birds went over his loft with the rest, carrying on to Leigh, where the others dropped in to their lofts and his birds came back the two miles to their lofts on their own. Some fanciers train young birds by flying them with experienced older birds as "teachers".

Not only can pigeons be trained to home to a lighted loft or to a lamp where they are fed, but they do it regularly to unlighted lofts on big races without any special training for night-flying. In the peace-time races from Rennes and San Sebastian to Scotland not many birds homed on the race day, and while some stayed out overnight resting and continued next day several cases were duly authenticated of pigeons seen arriving at their lofts at midnight or 2 a.m. Truly there is much twilight in Scotland during the summer race season, but there are several cases in the records of birds homing to their lofts through 50 to 300 miles of

storm, fog, snow or overcast night. Racing pigeons are, of course, encouraged to home by feeding them only at their home loft, which therefore offers the food memory to a hungry bird, and they are kept fit and light in training by receiving not more than one ounce of corn a day. They will stop for water en route but seldom for food. They will also home against a head wind.

Selective breeding and years of training have extended the strong homing instinct of the pigeon from its inherent nesting-territory memory until it has become an ability to home to the loft whether the bird is nesting or not. By feeding pigeons always in one loft and watering them always in another they will home backwards and forwards between the two lofts, whereas normally they have to be conveyed to the race point for liberation for their flight home. As with all special forms of homing, birds have to be trained from a young age to adapt themselves to any specialised methods and in this instance one loft can be used to feed and shelter the young birds which are taken to some sort of portable loft, or "coop" as the Americans say, within sight of the food loft every time they are given a drink. Soon the youngsters learn what they can get from each loft and, having had a drink and been released from the water-loft, they fly to the home loft for food; released after food they fly to the water-loft for a drink. If the distance between the water-loft and the home loft is then increased gradually until one loft is beyond the birds sight, they will look for it, recognise and continue to use it even though it be two or twenty miles away. This, I believe, was originally demonstrated in America.

The most consistent pigeons for long-distance race successes are third and fourth season birds, but with all youngsters (under 1 year old), no matter how well-bred, there is always the danger of them getting lost. It is unwise to consider a pigeon reliable as a homer until it has passed the yearling stage. Orientation develops with age, improving as the bird approaches its prime of life and then declining with old age. (This does not imply that young birds cannot home long distances; a $6\frac{1}{2}$ months-old hen bird tossed up by itself homed 500 miles, 280 miles of which crossed water). The best condition in which old birds home long distances is when 7 to 10 days on eggs, and the best from youngsters is generally when they are flying out freely and are not too advanced in their moult. Most of the old Belgian fanciers who pioneered long-distance racing never raced their cock birds, but the belief behind that practice has long been proved to be fallacious.

Summarising, I am of the opinion that sight and memory play the largest part in homing, plus secondary stimuli from such attractions as feeding at the loft, the eggs or young in a nest, the presence of eggs or young in a nest, or a mate being driven by an amorous cock bird, or by two cocks in rivalry. I believe it is primarily associated with what ornithologists term "territory right", but it has been bred into pigeons to function at all seasons. I do not associate it with the migration habits of birds, for homing is always an attraction to a place, whereas migration is at one season a movement *to* an attraction and at another a movement away *from* something; homing instinct, too, is not stimulated by light to the extent that migration is. But experiment and observation have yet to disclose to us how the homing bird routes itself along a distance it has not previously seen and before its sight-memory of its home loft can function.

CHROMATOGRAPHY (*Continued from page* 121)

such as tartaric acid, can exist in two forms which are chemically identical and physically differ primarily in their effect on polarised light. Such pairs of compounds are called optical isomers, because they differ only in their optical properties. Their close similarity makes their separation difficult: the stock method is to combine than with a single optical isomer of a different kind and separate the resulting compounds. Some chromatographic separation can be obtained when a mixture of the optical isomers is filtered through a column consisting of an optically active adsorbent such as lactose.

To return to the subject of inorganic chromatography mention should be made of the use of the method in the separation of isotopes. Much work has been done by Urey and his collaborators (this team is world-renowned for their work in connection with "heavy water") on the separation of lithium isotopes by chromatographic methods. They used adsorption columns up to 100 feet in length. In one experiment 150 cc. of a 10% solution of lithium chloride was passed through such a column (of alumina) and the chromatogram was developed with 3% sodium chloride solution. They found a ratio of 14·1 between the amounts of the two isotopes Li^7 and Li^6 in the head of the adsorption band, and a ratio of 8·8 in the tail, indicating that a definite separation had occurred. In the middle of the zone, representing 98% of the original material, the ratio was unchanged from the normal value of 11·7. In other experiments a separation of the same order was effected with potassium isotopes.

This account of chromatography has necessarily been a very general one but the following points may be stressed. In the first place one cannot fail to be struck by the completeness of Tswett's work. A new chemical method is often a long time growing and many different workers make substantial contributions before a satisfactory technique is established. While the past ten years have seen a very great increase in the use of chromatography there have been relatively few important modifications of the procedure laid down by Tswett. For reasons that have been mentioned his method at first made little impression; now that it is bearing fruit due credit should be given to its discoverer. Secondly, the point should be emphaizsed that in chromatography we possess an analytical method which is at least as comprehensive as any of those which are more established in laboratory procedure. This is unfortunately not yet fully appreciated and the method can certainly be profitably used in many laboratories where it is still largely unknown.

READING LIST:

1. Principles and Practice of Chromatography. By L. Zechmeister and L. Cholnoky. (Translation from 2nd German edition by A. L. Bacharach and F. A. Robinson. Chapman and Hall, London, 1941).

2. Chromatographic Adsorption Analysis. By H. Strain (Interscience Publishers, New York, 1942).

3. An Introduction to Chromatography. By Trevor I. Williams. (Blackie. In Press).

CHROMATOGRAPHY—the term "chromatographic adsorption analysis" is perhaps more descriptive—is rapidly becoming one of the most important methods of chemical analysis. Originally devised at the beginning of this century by a Russian botanist for the separation of the mixture of pigments found in the green leaf, the technique went unnoticed for many years. To-day its application is extending rapidly; recently, for instance, the use of chromatography has contributed much to the isolation of both penicillin and vitamin K.

Chromatography

TREVOR I. WILLIAMS, B.A., B.Sc.

IN the early years of this century the Russian botanist Tswett, working at what was then the Russian University of Warsaw, carried out experiments which resulted in the development of an entirely new method of chemical analysis. This method of analysis is known as chromatography. The name is derived from the Greek *chroma* and *graphia*, literally colour-writing, because the method was first used for the separation of pigments. The subject of chromatography is conveniently and logically introduced by describing one of Tswett's typical experiments.

As a botanist Tswett was interested in the pigments present in the leaves of plants. When green leaves are ground up and the resulting pulp is extracted with a suitable solvent, such as alcohol or petrol, a greenish-yellow solution is obtained which contains a number of different pigments. Tswett allowed such a solution to percolate through a column of powdered calcium carbonate contained in a vertical glass tube (Fig. 1). At first the carbonate at the top of the column took up most of the pigment and became uniformly green in colour. As more of the solution passed through the column, however, a striking change was seen. As might be expected the colour spread gradually down the column of carbonate but in doing so it no longer remained uniform. In effect the different pigments in the original solution washed through the column at different speeds. As a result they became separated, in the same way as runners in a race sort themselves out according to their different speeds. The column became marked with yellow and green rings corresponding to the different pigments present in the mixture. When the original solution was followed by a little pure petrol the separation of the rings became even more pronounced and they were divided from each other by rings of pure white carbonate. The final appearance of a column of calcium carbonate treated in this way is shown in Fig. 2. Such a column is known as a chromatogram.

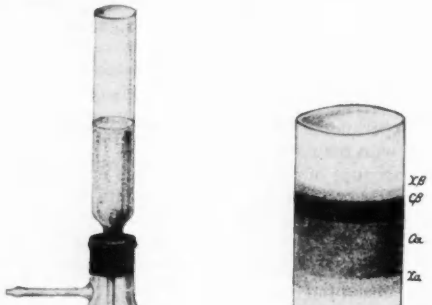


FIG. 1.—(*left*) Tswett's chromatographic apparatus. The vertical glass tube is plugged with cotton wool at its lower end and contains a column of powdered calcium carbonate. The filtrate from the column is collected in the glass Buchner flask.

FIG. 2.—(*right*) Chromatogram formed by filtering a solution of leaf pigments through a column of calcium carbonate. The individual pigments have become arranged in successive bands; the letters indicate their position in the column according to the following key: $x\beta$, xanthophyll *b* (yellow); $c\beta$, chlorophyll *b* (olive green); $c\alpha$, chlorophyll *a* (bluish green); $x\alpha'$, xanthophyll a' and a'' (yellow); $x\alpha$, xanthophyll *a* (orange yellow). (After Tswett).

When separation of the coloured rings was sufficient the tube was allowed to drain and the cylindrical column of damp carbonate was pushed out bodily. It was then cut transversely with a knife to separate the rings corresponding to the various pigments (see Fig. 3). Each fraction of coloured carbonate so obtained was shaken with a little alcohol, which washed out the pigments, the resulting solutions were filtered free from the insoluble calcium carbonate and could then be used for the further investigation of the individual pigments. In a single experiment Tswett was thus able both to demonstrate the complex nature of the leaf pigments and to isolate several of the components of the mixture. As one author has put it "the chemist's dream was fulfilled; substances that had been mixed together could be cut apart with a knife".

Tswett noted the close analogy with the analysis of light by means of a prism and wrote: "Like the light radiations in the spectrum, so is a mixture of pigments systematically separated on the calcium carbonate column into its constituents, which can then be qualitatively and quantitatively determined".

To explain why the pigments behave in this rather unexpected way something must be said on the subject of adsorption. It has been known for centuries that charcoal has the property of decolorising many solutions when shaken with them. This is due to the fact that the pigment

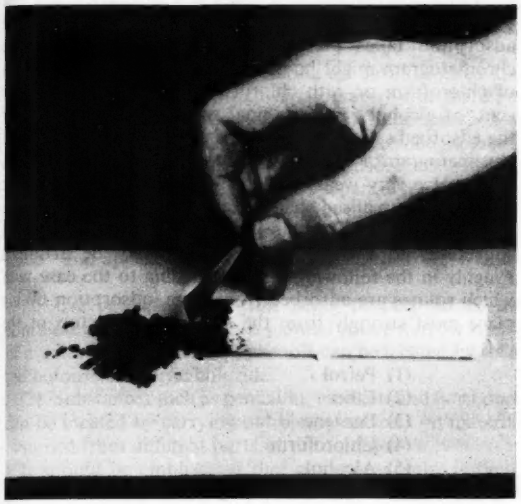


FIG. 3.—When the bands on the column are sufficiently distinct that latter is pushed out bodily and the parts bearing the various pigments are separated with a knife.

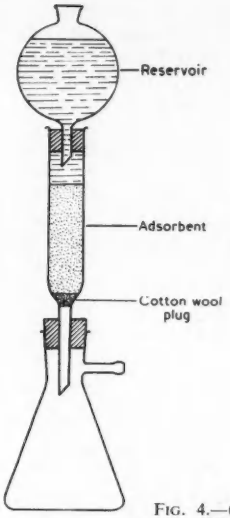


FIG. 4.—(*left*) Diagram of chromatographic apparatus fitted with reservoir which enables comparatively large volumes of solution to be dealt with without refilling.

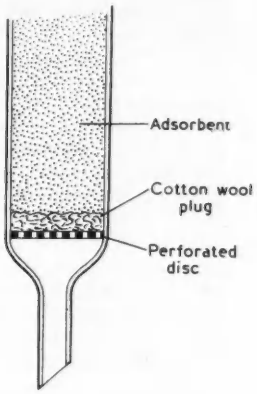


FIG. 5.—(*right*) The column is more easily pushed out if its lower end rests on a rigid perforated plate. Porcelain plates are commonly used.

molecules arrange themselves tenaciously on the surface of the charcoal. Although the film so formed is probably only a single molecule in thickness the relatively large area presented by a fine powder such as charcoal enables it to take up, or adsorb, considerable quantities of pigment in this way. Adsorptive properties are possessed by a great many substances other than charcoal. As it is essentially a surface phenomenon it becomes of practical importance only when the substances are finely powdered and so present a very large surface to the solution. Adsorption is a reversible process. The tenacity with which adsorbed substances are held depends, among other factors, on the nature of the solvent and the concentration of the solution from which adsorption takes place. In effect this means that the adsorbed film can be removed by washing, though not necessarily with the same solvent as that used in preparing the original solution.

Let us now apply this very brief account of adsorption to the interpretation of Tswett's experiment. As the solution filters through the calcium carbonate the pigments are adsorbed. Those with the greatest affinity for the adsorbent remain near the top of the column, displacing those with less affinity. The rings move down the column because the adsorption process is reversible. The pure solvent washes off a little of the pigment and this is re-adsorbed lower down the column when it comes in contact with fresh carbonate. From a solution of chlorophyll in alcohol adsorption takes place relatively weakly and hence this is a suitable solvent to use for finally removing the individual pigments from the separated parts of the column.

Tswett's work was carried out in the early years of this century, but for various reasons it attracted little attention until the '30's. In spite of intensive investigation and use of the method during the past ten years there have been few fundamental developments. Tswett himself created an entirely new type of technique, virtually complete in itself, and for this he deserves great, if belated, credit.

Development of Chromatographic Technique

There are a number of reasons for the neglect of so important a discovery. One is that much of Tswett's work, and in particular his monograph on the subject, was published only in Russian. Equally, if not more important, is the fact that at that time chemists and biologists were not greatly interested in the type of problem in which chromatography possesses definite advantages over more orthodox methods of analysis. Organic chemists were preoccupied with synthetic work: when they investigated natural substances they turned to those which were readily obtainable in reasonable quantities in the pure state. Biology was much further removed from the physical sciences than it is to-day. In more recent years the discovery of the vitamins, hormones, anti-bacterial mould products and other substances has focussed attention on substances of physiological importance. The chemist is no longer content to investigate only those substances which are comparatively easily obtained. Now he is frequently anxious to isolate substances which, at any rate in the early stages of an investigation, can be detected only by their physiological effect. To deal satisfactorily with problems of this kind it has become necessary to find methods for the speedy isolation of various constituents, often very minor ones, of very complex mixtures. It is in this type of problem that chromatography can be used with particular advantage.

To appreciate the value of the method it must be considered in relation to the older methods of analysis. The majority of these are based on differences of volatility or solubility. As examples of the former may be mentioned

simple distillation, distillation under reduced pressure, steam distillation and sublimation. Processes based on solubility relationships include extractions with, or partition between, different solvents, precipitation with specific reagents and simple crystallisation. Chromatography provides an analytical method, of very wide application, which is based on an entirely different principle, namely adsorption. It is largely an empirical method and can be applied directly to mixtures of very great complexity. The name chromatography arose, as already described, from its original use in the separation of coloured substances, but Tswett himself made use of the method in the separation of colourless substances and the past ten years have been marked by greatly increased application in this field. Used in conjunction with other methods, such as those mentioned briefly above chromatography has played a great part in the biochemical advances of the past decade.

Adsorbents and Solvents used

Previous mention has been made of the use of calcium carbonate and charcoal as adsorbents. A very great number of other substances have been used, Tswett himself listing over one hundred. To be of practical use an adsorbent must, in general, conform to the following conditions:

(1) It must be insoluble in the solvents used; (2) it must not react chemically with substances filtered through the column; (3) it must be sufficiently active (i.e. possess sufficient adsorptive affinity) to prevent the substances under examination running through the column but not too active to prevent the bands moving on washing with fresh solvent; this washing process, which is an essentially part of chromatography, is known (by analogy with photographic development) as the development of the chromatogram; (4) it should preferably be colourless so that the bands can be readily seen; (5) different samples of the adsorbent should give similar results; this condition can generally be fulfilled by using specimens from the same source bearing the same trade name; samples from different sources often show marked differences in activity; (6) it should be reasonably cheap.

Much the most generally used adsorbent to-day is alumina (aluminium oxide). This is insoluble in both watery and organic solvents. Its activity can to some extent be controlled; it is reduced by exposure to damp air and increased by heating. A number of commercial firms are now marketing brands of alumina of standardised activity specially for chromatographic work. Other common adsorbents are magnesia, slaked lime, fullers' earth, zeolites (a group of minerals, chemically aluminosilicates, of which the best known member is used in water softeners), talc and sugars.

The effect of different solvents on adsorptive affinity has already been mentioned. From some adsorption takes place very much more readily than from others. In general the original solution is made with a solvents such as petrol or benzene, from which adsorption takes place readily. The concentration of the solution should not exceed 5% as a general rule. The chromatogram is developed, to increase the separation of the bands, with the same solvent or one from which adsorption takes place somewhat less readily. The latter solvent is often not used as such but is mixed with the original solvent. Thus if adsorption takes place from chloroform solution the chromatogram might be developed with further quantities of chloroform or with chloroform containing a few per cent. of alcohol For the final washing or "elution" of the adsorbed substances from the different fractions of the chromatogram a solvent is used from which adsorption takes place very weakly. Alcohol is commonly used. It must also be realised that choice of a solvent is to some extent determined by the solubility relationships of the substances to be analysed. Solvents may be arranged roughly in the following series according to the ease with which solutes are adsorbed from them, adsorption taking place most strongly from the solvents at the top of the list:

(1) Petrol
(2) Ether
(3) Benzene
(4) Chloroform
(5) Alcohol
(6) Water (depending on *p*H.)
(7) Pyridine
(8) Acetic acid

The appearance of the final chromatogram depends on both the adsorbent and the solvent used. Finding a suitable combination is largely a matter of trial and error but with a little experience this can generally be done quite quickly.

Simple Apparatus

The apparatus necessary for chromatography is very simple and can be constructed cheaply and quickly in any laboratory. The original apparatus used by Tswett has already been illustrated (Fig. 1) and modern apparatus is made on similar lines. It consists (*see* Figs. 4 and 5) essentially of a glass tube drawn out at one end; a plug of cotton wool, preferably resting on a perforated disc, is placed at the lower end; the plug serves as a filter to prevent the adsorbent from washing through. If desired the speed of filtration can be increased either by applying suction at the foot of the column or by applying pressure to the top.

The secret of success in chromatography is to pack the adsorbent uniformly. This is necessary in order to obtain regular bands which can be easily separated. In one method of packing the dry adsorbent is added bit by bit and persuaded to settle by gently tapping the tube. Alternatively the lower end of the tube can be closed and solvent added until it is half-full. It is then clamped vertically and the dry adsorbent sprinkled in gradually. The powder settles slowly and a uniform column is built up. During chromatography great care must be taken to see that the adsorbent is not disturbed.

The classical method of separating the different bands forming the chromatogram is to push out the column and chop it up. Increasing use is now being made of the "liquid chromatogram". In this development is prolonged until the different bands wash right through the column. Each is then collected in a separate receiver.

The size of the column is dictated largely by the amount of material to be analysed. For microchemical work

columns as small as 1 mm. × 20 mm. can be used. At the other end of the scale are columns containing hundreds of pounds of adsorbent.

Adsorbents are capable of taking up both coloured and colourless substances and chromatography can therefore be used for the separation of colourless substances. The necessary modification in technique is to provide methods, other than visual ones, for locating the adsorbed substances on the column. Each case requires separate treatment but the following methods have proved of fairly general value.

(1) *Use of ultra-violet light.* Many substances "fluoresce" and appear coloured when examined in ultra-violet light.

(2) *Use of indicators.* After being pushed out of the containing tube the column is painted with a narrow streak of a suitable reagent. E.g. phenols can be located by their red colour with ferric chloride.

(3) Substances such as penicillin, vitamins and hormones can be located by carrying out biological tests on material obtained from different parts of the column.

It should be emphasised that chromatography is theoretically and practically as applicable to colourless substances as to coloured ones.

Inorganic Chromatography

This is one of the few major fields in chromatography that Tswett does not appear to have explored. It is of recent development and much still remains to be done. Sufficient has been discovered, however, to show that chromatography offers a valuable new method of inorganic analysis, particularly in the separation of cations. Aqueous solutions are used and alumina is almost invariably the adsorbent selected. The order of adsorption of cations appears to depend on valency, trivalent ions being the most strongly adsorbed. Fig. 6 shows the chromatogram formed when an aqueous solution of copper and cadmium sulphates was filtered through an alumina column. Initially a blue zone of copper was formed at the top of the column with the colourless cadmium beneath it. On washing the column with water containing hydrogen sulphide the zones became dark brown and orange respectively, owing to the formation of the corresponding sulphides.

Of particular interest is the Permutit "Deminrolit" process for preparing the equivalent of distilled water from natural water. The water is passed first through a zeolite column on which ion exchange takes place. The cations are replaced by hydrogen ions and the issuing solution contains the acids corresponding to the original anions. This solution is then passed through a second column in which the acids are removed by an adsorption process. The issuing water is practically free from mineral material.

The chromatographic method of analysis is capable of very wide application. Mixtures of very varying types can be resolved by judicious choice of solvent and adsorbent. Like methods based on distillation or crystallisation chromatography lends itself to fractionation. A preliminary purification may be effected with one combination of solvent and adsorbent and the resulting fractions can then be further purified by means of the same or a different combination. In dealing with unstable substances the chromatographic method is of particular value since the experimental conditions are very mild.

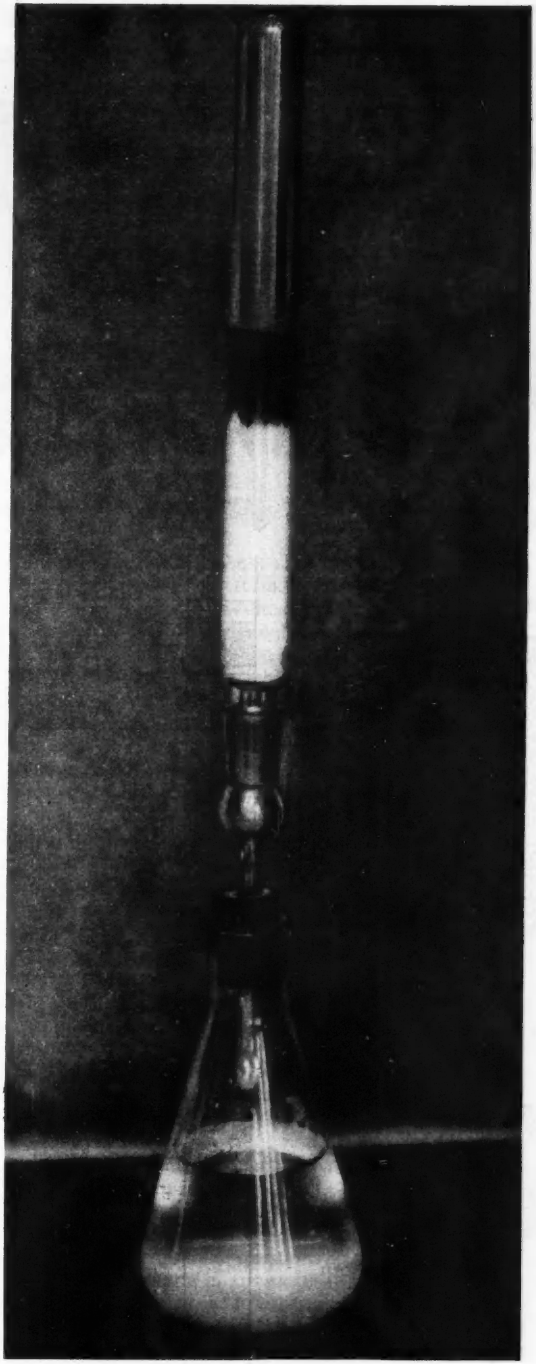


FIG. 6.—A solution containing copper and cadmium sulphates has been filtered through a column of alumina. The adsorbed metals have been converted to their deeply coloured sulphides by washing the column with a solution of sulphuretted hydrogen.
TOP: Dark brown (copper). BOTTOM: Orange (cadmium).

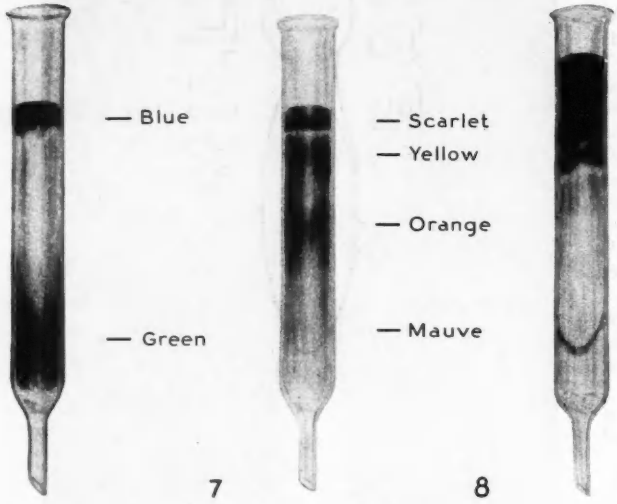


FIG. 7.—Separation of methylene blue and malachite green by filtering a solution of these dyes through a column of alumina. By development with water the whole of the malachite green can be washed through the column.

FIG. 8.—Many commercial dyes are far from pure. This chromatogram shows that a sample of commercial eosin contains at least four constituents.

FIG. 9.—Chromatogram obtained by passing a solution of crude terreic acid in ether through a column of alumina.
(a) Appearance in daylight. (b) appearance in ultra-violet ligh. The ultra-violet reveals bands that are not apparent in daylight. The colourless terreic acid is located immediately above the ochre band seen in (a).

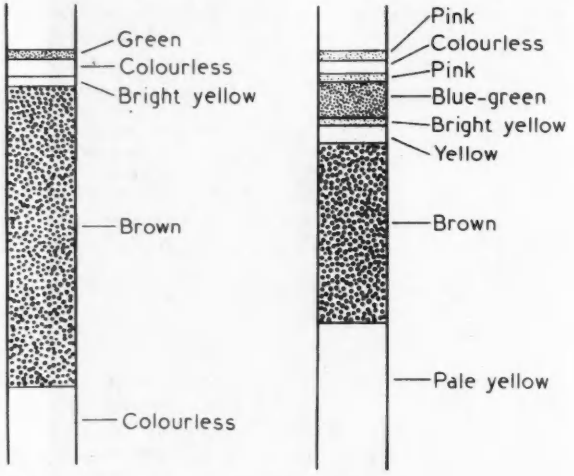
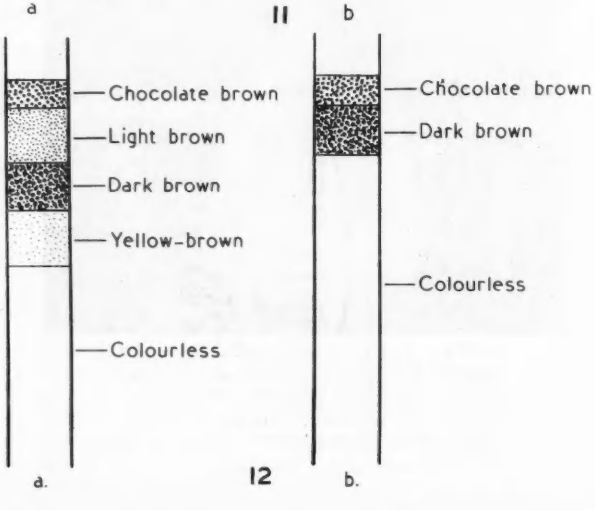
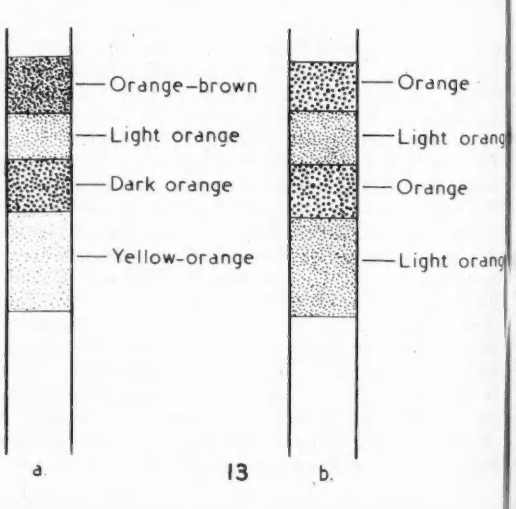


FIG. 11.—The diagram shows the characteristic chromatogram of butter obtained when a solution in benzene is filtered through an alumina column. (a) Appearance in daylight; (b) Appearance in ultra-violet light.

FIG. 12.—This diagram illustrates the difference between the chromatogram of natural Balsam of Peru (a) and that of an artificial product (b). The substances were in each case dissolved in alcohol and filtered through alumina.

FIG. 13.—Characteristic chromatogram of saffron. (a) Appearance in daylight; (b) Appearance in ultra-violet light.





Tswett's original work was the investigation of plant pigments. He was able to show that chlorophyll and leaf-yellow were not simple substances but mixtures of several pigments. It was natural that when interest in Tswett's method was revived in the '30's its first noteworthy success should again have been with plant pigments. In 1931 carotene was separated into α- and β-carotene by Kuhn and his collaborators. It is interesting that in this work a prophecy made by Tswett some twenty years earlier was fulfilled. In 1910 he wrote: "Very likely leaf carotene is not a chemical entity but a mixture of two or more homologues which it may be possible to separate from one another by means of the absorption method." Since 1931 chromatography has become an integral part of the experimental study of natural pigments.*

The step from natural to artificial dyestuffs is a short one. Tswett himself subjected the synthetic dyes Oil Blue and Sudan III to chromatographic analysis. More recently it has been shown that many combinations of water-soluble dyes can be separated simply by filtering their aqueous solutions through columns of alumina. Fig. 7 illustrates the separation of meyhylene blue and malachite green in this way. The purity of many commercial dyes can be tested by chromatography. Fig. 8 shows the complex chromatogram obtained when an alcoholic solution of commercial eosin (a red dye used in preparing red ink) is filtered through a column of alumina; the chromatogram was developed by washing with aqueous alcohol.

The value of chromatography in the isolation of colourless substances has been mentioned. The technical literature contains scores of examples of which only a few can be quoted here. In the preparation of pure crystalline penicillin chromatography proved the most valuable analytical method available. The position on the column of the colourless penicillin was found by testing the anti-bacterial properties of samples taken from different points. Terreic acid, another anti-bacterial mould product, has been isolated on alumina from ethereal solution; Fig. 9 illustrates the appearance of the final chromatogram in both daylight and ultra-violet light.

In the investigation of vitamin K, for which two of the leading workers have recently received the joint award of a Nobel Prize, chromatography was the only analytical method employed. Here the crude starting material—dried lucerne, otherwise known as alfalfa—contained less than 0·001 % of the pure vitamin, and the impurities were numerous and complex. It is with such complex mixtures that chromatography is of outstanding value.

The use of chromatography demands no theoretical knowledge and good technique is largely a matter of practice. The method is therefore valuable for the carrying out of routine analyses by technical staff. It is finding increasing use in the analysis of such important natural mixtures as foods, drugs, dyes and oils. Sophistication of wine, for example, can frequently be detected literally at a glance. Fig. 10 shows the characteristic chromatogram of red wine when filtered through a column of alumina. If a dye such as Bordeaux Red has been added to improve the appearance—and price—of the wine this is immediately apparent since it washes quickly through the column and can be isolated from the filtrate and identified. Butter is

*A recent biochemical review lists 25 different pigments obtained from plants, many of them by chromatographic methods.

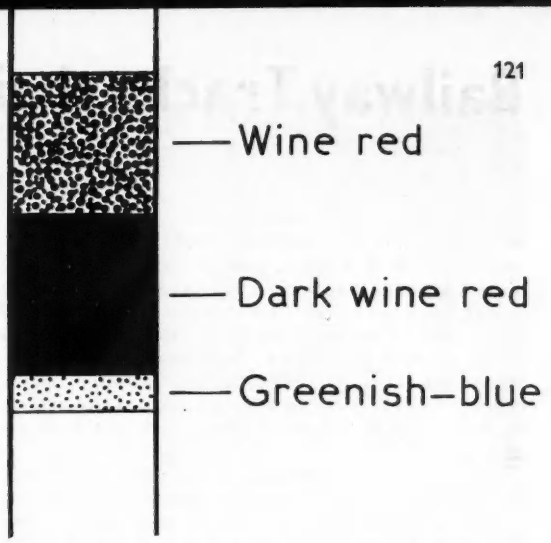


FIG. 10.—Characteristic chromatogram of a red wine adsorbed on alumina.

another product which gives a characteristic chromatogram (Fig. 11) and deviations from the normal appearance indicate the presence of adulterants. Summer and winter butters give somewhat different chromatograms.

Chromatography is finding increasing use in medicine. Many natural drugs give characteristic chromatograms. Fig. 12 for example illustrates the difference between the chromatogram of natural Balsam of Peru and an artificial product. Low grade saffron (a drug derived from the autumn crocus) can be readily distinguished from preparations of higher pharmacological purity by the greater number of bands formed on adsorption on alumina. (Fig. 13). The method has been used also in the analysis of urine, both normal and pathological. Coproporphyrin I, a pigment which is present in normal urine to the extent of one part in one hundred million, has been isolated by adsorption on a mixture of cotton fibre and asbestos. In congenital porphyria uroporphyrins (reddish-yellow pigments) are the chief porphyrins excreted in the urine. Two isomeric uroporphyrins have been isolated from the urine of a patient suffering from this disease by adsorption on talc.

Chromatography has found numerous applications in academic fields. For example, in many branches of research it is often necessary to determine whether a substance is homogeneous or not. Does a highly active vitamin concentrate represent the pure vitamin or is it contaminated with inactive impurities? Has a substance, known to be pure when initially prepared, decomposed on storing? Is a commercial reagent as pure as its makers claim? These and similar questions are of daily occurrence in the laboratory and in answering them chromatography is a valuable supplement to other methods. A useful test for homogeneity is whether the substance can be resolved chromatographically into two or more components. Conversely the identity or otherwise of two closely similar substances can be determined accordingly as they form one band or two on chromatographic analysis.

Limited success has been obtained with chromatography in resolving optically active substances. Many compounds,

(*Concluded on page* 115)

Railway Tracks their Design and Testing

FRANK FERNEYHOUGH

WITH the greatly increased demands of gathering progress, more and more do scientific principles and aids have to be applied to our railway tracks. The factors most damaging to rails are those connected with speed and weight. Just before this war started, many express trains were running at 80 and 90 miles an hour; for experimental purposes speeds up to 125 miles an hour had been achieved. Many complete passenger trains weigh as much as five and six hundred tons, and freight trains may weigh anything up to 14 to 15 hundred tons.

Apart from all the manual and technical staff engaged in building, installing and maintaining the track, British railway companies each have research departments where the results of the many experiments are collected and tabulated by the experts; and new methods of track lay-out evolved.

Super-Elevation

One aspect of railway track design that has engaged their attention for some time is that of super-elevation or cant on curves, in which the outside rail on the curve is higher than the inside rail, sometimes by as much as five or six inches. By the scientific use of super-elevation, much wear and tear on track and rolling stock is avoided, and a far higher standard of comfort for passengers is obtained. Speed is greatly increased, for a well-planned curve enables a train to sail along almost as smoothly and sweetly as on straight line.

The centrifugal force associated with a moving train enters into the determination of the super-elevation required on a curve of given radius. If a stone is tied on an inextensible string and whirled round, so that it describes a curve of given radius, then the faster the stone moves the greater the force in the string required to keep the stone moving in a curved path. The same is true of a curved railway track: here a certain degree of super-elevation of the outside rail tilts the train and makes available a certain proportion of the weight of the train to counteract the centrifugal force. If the train runs round the curve at the correct speed, the train (and the passengers) will feel no resultant sideways force. If the speed is less than this the passengers will feel that the train is tilted inwards, while if the speed is excessive the train and passengers will feel a centrifugal force tending to draw them outwards.

To ascertain the super-elevation required on a given curve, the first thing is to find out its radius. This is done by placing a chord on the curve, then measuring the distance from the centre of the chord to the rail. This distance is called the "versed sine," or more commonly, the "versine". For all practical purposes on the railways, the following formula for finding radius is used:

$$\text{Radius} = \frac{\left(\frac{C}{2}\right)^2}{2V}$$

C and V representing Chord and Versine respectively. Railway inspectors and permanent-way men have a much quicker method of finding out the *approximate* radius of a curve. With a 66 ft. (one chain) chord, the versine in inches divided into 99 gives the radius of the curve in chains. Thus, a three-inch versine would denote a 33 chain curve.

For average weights and speeds of trains, the following formula is used for working out the super-elevation:

$$\text{Super-elevation (in inches)} = \frac{0{\cdot}06\ v^2}{r}$$

v representing the speed of the train in miles per hour, and r the radius of the curve in chains.

A curve with constant radius throughout offers no particular difficulty, but many curves are compound, made up with several curves of varying radii, and in all directions. For these, much greater skill and care is required in their measurements. In all cases, measuring the versine is one that needs extreme accuracy, for even with a sharp curve, the versine revealed by a chord of 66, 100 or 132 feet—the usual lengths—is very small.

Though super-elevation does not usually exceed 4½ in., there are several instances where it is much higher. On the L.N.E. Railway between Manchester and Sheffield are two sharp curves of 31 chains radius canted to the extent of six inches on the down line; one is at Crowden Station, the other near Valehouse Signal Box. The maximum speed allowable is just over sixty miles an hour. But these are very exceptional.

As trains vary so considerably in weight and speed, computation has to be made on the basis of average conditions; there is no other way. If a train is travelling over a curve at less than average speed the weight, instead of being fairly evenly distributed on both rails, is heavier on the inside rail. The opposite effect occurs when trains travel at greater than average speeds. A large margin of safety is allowed in comprising the degree of super-elevation and trains could safely travel on curves at much higher speeds than are now permitted.

From these points, it might appear that if a train comes to a sharp curve, it would immediately jolt on to a super-elevated rail. The result of this would be disastrous, except at very low speeds; and so an even finer set of principles is met with, that of transition-curve super-elevation. The idea is that instead of having a curve of one radius throughout, there is at first a curve of such long radius as to be almost a straight line and with a super-elevation only a fraction of an inch. A little further on, the curve sharpens slightly, with a proportionate rise in super-elevation; the procedure is repeated until the sharpest part of the curve and the highest super-elevation are reached, the grading of the curve is then reversed until the straight line is again reached.

This method of curving has been in use for some years by all the railways. Already hundreds of miles of line have been re-aligned on the principles of the transition-curve, thus making for a saving of many hours running time each day, and much unnecessary wear and tear. Further work on these lines is anticipated in the near

future, especially at complicated junctions with lines curving in several directions on varying gradients where, for safety's sake, there exist at the present time heavy restrictions on speed.

Curves entail far more friction than straight-line track, and at certain busy sections the side-cutting that occurs on the outside rail is such that frequent renewal is necessary. A method widely used to reduce this damaging friction is that of lubricating the particular part of the rail, and the flanges of the wheels, by means of an appliance fitted on the outside rail near the commencement of the curve. One such type of appliance contains an oil bath, with a felt pad partly immersed in the oil. The felt pad fixed in such a position that each wheel passing against it squeezes out an amount of oil between the wheel flange and the rail. Sufficient allowances are made to avoid undue wear of the felt pad. A second type of appliance is also actuated by the passage of wheels, which actually works a mechanical pump, thus pumping, by means of spring and piston, a small amount of grease to the greasing plates from the lubricant container to the wheel flanges and rail. Another type of apparatus for lubricating rails on curves is one worked from the locomotive, feeding oil to the wheel flanges. But this is not so efficient as the track appliances, mainly because the tops of the rails also become lubricated, causing driving wheels of engines to slip and reducing the efficiency of braking. It has been estimated that the life of rails on curves so fitted has been increased three and four times, ample evidence that rail lubrication is effective. Though there is also an extension on the life of wheels, no reasonable estimate is practicable.

Track Testing

On the track itself, every inch is thoroughly examined each day by patrolmen, or "platelayers" as they are still called. In addition to seeing that the rails are firmly keyed in the metal "chairs", and that the bolts holding the chairs to the sleepers are secure, these men have to watch out for any indication of subsidence, gaps under sleepers, cracked rails, insecure joints, or any other defect, giving what attention is necessary. It is this daily examination, together with certain other periodical examinations of bridges, points, and other apparatus, that is the backbone of track maintenance, and one which is regarded as extremely important. But with the advance of research, much of this manual work can be avoided. As a guide for the platelayers, stumps with the super-elevation figures are often placed along the lines, so that levels may be maintained without having to solve lengthy mathematical problems or to make continual reference to plans and diagrams.

Help is also given by a useful little track instrument called a "Voidmeter". With the continuous hammer blows of high speed trains a gap under a sleeper will often result, a gap due to slight subsidence and capable of causing a train to lurch slightly.

The difficulty lies not so much in tracing a sleeper under which a gap exists (generally known as a "hanging" sleeper,) for this can usually be detected from the sound made when tapped with a metal bar, but in judging the

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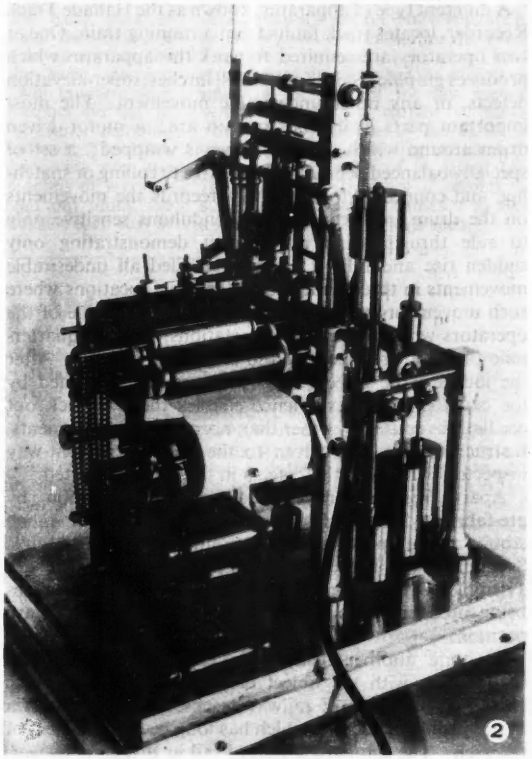

2

FIG. 1.—The Hallade Track Recorder in use. (*Photograph by courtesy of the G.W.R.*). FIG. 2.—The photograph shows the construction of the instrument. (*L.N.E.R. photograph*).

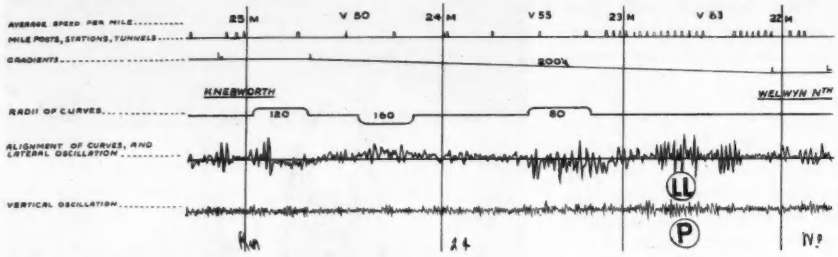


FIG. 3.—Part of record taken with Hallade Track Recorder on the Kings Cross—Hitchin line. The code letters are instructions to permanent-way inspectors: LL means "Line and level of straight track needs attention" and P stands for "Packing of sleepers needs attention" *Reproduced by courtesy of the L.M.S.*).

amount of packing, by means of ballast chippings, that is required to make the sleeper firm in its bed again. This is where the Voidmeter plays its main part. Clamped on to a stake in the ground, the Voidmeter is so fixed that it comes into contact with the "hanging" sleeper. When a train travels over the rails, the faulty sleeper is depressed afresh as each wheel passes over it, thus causing the spring pointer to push round a second pointer that stays in position at the furthest point to which it has been pressed. After each depression by the moving wheels, the spring pointer returns to zero. When the train has passed, the Voidmeter is found to record so many units with the second pointer, indicating to the permanent-way man how much packing is required, thus saving much time that would otherwise be spent by trial-and-error methods.

A different type of apparatus, known as the Hallade Track Recorder, locates track faults from a running train. One or two operators are required to work this apparatus which produces graphic records of bumps, lurches, super-elevation defects, or any other undesirable movement. The most important parts in its construction are: a motor-driven drum around which squared paper is wrapped; a set of specially balanced pendulums, sensitive to rolling or snatching, and connected to a pen that records the movements on the drum; a second set of pendulums sensitive only to side thrusts; and a third set demonstrating only sudden rise and fall. Thus are recorded all undesirable movements in three dimensions, the exact locations where such movements take place being indicated by one of the operators who watches out for stations, tunnels, quarter-mile posts on the lineside, and similar landmarks. After the journey, the three graphs are carefully examined by the experts, whose experience enables them to pick out oscillations caused by other than normal train movements. Instructions are then given to the local permanent-way inspectors who have the defects in the track corrected.

Apart from general maintenance, construction by pre-fabricated methods overcomes the need for much labour being spent on the line among moving trains. Sections of line, and complicated junctions and points are assembled at the workshops, special track-laying machines being used finally to place the ready-made sections into position.

In quite another field, more experiments are being carried out, with the object of perfecting welded joints. In the construction of railway tracks, the rail joint is a major problem, and one which has long been the subject of research. The standard length of rail in Britain is 60 feet, which means a continuous rhythmic bumping every 20 yards as the wheels pass over the joints. Apart from the discomfort to passengers, the adverse effect on rolling stock and track is heavy, the cost of maintenance high. The main difficulty with welded rails is that no space can be allowed for thermal expansion as can be done with short rails. But well-considered tests and experiments with different types of metals and the introduction of the flat-bottom rail have now proved that rails welded in lengths up to 2,000 feet do not buckle in hot weather.

Though all the British railways have experimented widely in welding, the L.P.T.B. tests with rails welded together in lengths up to three hundred feet are probably the most notable, and a considerable mileage has been laid down using this technique. On the tube railway where quieter running is even more desirable, and on surface electric lines where trains are very frequent, there is perhaps greater need for the possibilities of welding to be explored.

Hand-in-hand with the development of welded rails is that of the growing use of the flat-bottom track. The present standard of rail in use in this country is known as the bull-head, but there is every indication that it will be superseded in time. The main physical difference is that the flat-bottom rail has a base that is about twice as wide as the base of the bull-head. Pound for pound, flat-bottom track is nearly 40% stronger in the vertical plane, and the wider base gives much greater lateral stiffness. With the track kept in better alignment, much economy in maintenance is also effected. Ever conservative, a policy well justified by the world-renowned standard of safety achieved, the British railways have been experimenting since 1936 with the flat-bottom track. By 1939, the L.M.S. laid the first British flat-bottom track for express main lines; in 1943, the L.N.E.R. installed similar tracks for large-scale experimental purposes in England and Scotland.

It will be some years before sufficient data has been collected and experience gained to weigh up the advantages of performance exhibited by the flat-bottom track and to decide a settled policy, but so far the probability is that its use will increase considerably after the war.

With regard to gradients on the railways, it is not practicable to make any drastic changes, the lie of the land being the greatest influence; but even gradients can be put to scientific use. A good example is found in "hump" shunting. Certain marshalling yards are so constructed that engines push the wagons to a certain point at the top of a hump, after which gravity does the rest by running the wagons down into the various sidings for sorting purposes.

All these and many other aspects of railway track are studied carefully by experts who have been specially trained to enlist scientific aids to the full for the greater safety and speed of trains, and increased comfort of passengers.

The Night Sky in May

M. DAVIDSON, DSc., F.R.A.S.

The Moon.—New moon occurs on May 11d. 20h. 21m. U.T., and full moon on May 27d. 01h. 49m. The following conjunctions take place:

May				
8d. 16h.	Mars in conjunction with the moon	Mars	4°	N.
9d. 11h.	Venus ,,	Venus	7	N.
9d. 23h.	Mercury ,,	Mercury	2	N.
15d. 03h.	Saturn ,,	Saturn	0.2	S.
20d. 11h.	Jupiter ,,	Jupiter	4	S.

The Planets.—Mercury rises at 4h. 07m., 3h. 40m., and 3h. 20m. at the beginning, middle and end of the month respectively—that is, about half an hour before sunrise—and will not be an easy object to observe. The planet reaches its greatest westerly elongation on May 11. Venus rises an hour before the sun on May 1 and about an hour and a quarter before the sun on May 31, being conspicuous in the eastern sky. The planet is stationary on May 4 and May 24. Jupiter sets in the early morning hours, at 3h. 11m., 2h, 15m., and 1h. 10m., at the beginning middle and end of the month respectively. The planet is close to σ Leonis during May. Its distance from the earth varies from 444 to 484 million miles between May 1 and May 31. On May 15, Jupiter is stationary.

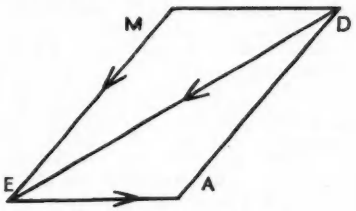
Saturn sets at midnight on May 1 and at 22h. 26m. on May 31, and is becoming a difficult object to observe for long in the evening. It is 886 million miles from the earth on May 1 and 920 million miles on May 31. The planet can be identified by the star ϵ Geminorum, being a little south of it.

Times of rising and setting of the sun and moon are as follows, the latitude of Greenwich being assumed:

May	Sunrise	Sunset
1	4h. 33m.	19h. 23m.
15	4h. 09m.	19h. 44m.
31	3h.49m.	10h. 06m.

May	Moonrise	Moonset
1	23h. 39m.	6h. 54m.
15	7h. 06m.	——
31	——	7h. 27m.

Where there are no times given this means that there will be no moonrise or moonset on the dates in the first column.



The speed with which a meteor strikes the earth's atmosphere is the resultant of the orbital speeds of the earth and the meteor round the sun.

Meteors.—During the early part of May the η Aquarid meteor shower is due but it will be difficult to observe as the meteors appear in the early morning hours and moonlight will interfere with observations. These meteors are due to the debris of Halley's Comet colliding with the earth. In DISCOVERY, July, 1944, there was a diagram showing how the earth collides with the debris of a comet (the debris being spread out along the orbit of the comet) and hence each year at the same time the earth passes through the debris, collisions with a large number of the particles taking place. The speed with which meteors strike the earth's upper atmosphere, where they are heated and rapidly dissipated owing to friction with the atmosphere, depends on the direction with which they are moving with reference to the earth.

The diagram shows why this speed varies. If EA is a line drawn to scale to represent the orbital speed of the earth (about 18½ miles a second) and also its direction, and ME, on the same scale, represents the speed and direction of the meteor (the speed and direction in the case of both the earth and the meteor being taken with reference to the sun), then the diagonal DE of the parallelogram represents in magnitude and direction the speed of the meteor with reference to the earth. It will be seen that DE can be less than either EA or ME, according to the position of M, or it may be greater than either. The speed of a meteor with reference to the sun, around which it is moving in an elliptical orbit, is about 26 miles a second at the distance of the earth from the sun, so that, generally speaking, ME is about 1.41 times EA. If the ellipse is not very elongated the speed of the meteor is less than 26 miles a second, but this figure can be taken as fairly accurate for most cases. The speed of a meteor is increased by the attraction of the earth, but the effect is very small in the case of the fast meteors. When, however, a meteor is moving slowly with reference to the earth, say when it is closely following the earth and overtakes it, instead of its speed being $26 - 18\frac{1}{2} = 7\frac{1}{2}$ miles a second, the attraction of the earth causes it to attain a speed of about 10 miles a second.

JUNIOR SCIENCE

Heat into Work

LIFE as we know it to-day in civilised countries, depends to a very great extent on machines which turn coal and oil into power. But that was not always so. Only a few hundred years ago nearly all the power in industry, agriculture and land transport was furnished by the work of human beings and animals. This does not mean that there were no machines. Man invented and used machines long before the time of written history, but those machines like levers and pulleys or the bow and arrow were not used to produce power but merely to transform and store it. You cannot throw an arrow with your arm fast enough to kill a bird in a high tree, but you can store the work of your arm by extending the string of a bow and then releasing the stored energy all at once, thereby imparting a high speed to the arrow. Again, you cannot lift a heavy stone by applying the force of your body directly, but you are able to lift the stone for a short distance by exerting your force over a large distance on the other arm of a lever.

However, when you travel in a bus, you are carried along by energy of the sun's rays which has been stored in the earth for many million years. The fuel on which the bus runs is, probably like coal, the remains of organisms of a bygone geological period which were built up, like all life, by the energy they received from the sun. When turning this stored energy into work in the engine we have to go about it in a peculiar and somewhat tortuous way. We do not straight away transform the chemical energy of petrol into work, but by first burning the petrol in the cylinders we turn its energy into heat. This heat is then used for expanding the air in the cylinder which by driving down the piston cranks over the engine and drives the bus. Very much the same happens in a locomotive, only we use coal instead of oil and water vapour (steam) instead of air. The electricity which drives trams, heats fires and gives you light is also nearly always produced by first burning coal and then using the heat to drive the dynamo which produces the current.

Only in very rare instances, as for instance in a torch battery, do we use the energy stored in chemicals directly, without first turning it into heat. This is very important for, as I shall tell you next time, heat is a form of energy which occupies a very peculiar place in the household of the universe. Meanwhile, just think about this. When a meteor drops out of the sky it heats up on impact with the atmosphere and the earth. But when you put later the cold meteor into a fire and heat it, it will not jump back into the sky.

K.M.

The Bookshelf

What is Life? The Physical Aspect of the Living Cell. By Erwin Schrödinger. (Cambridge University Press, 1944; pp. 100; 6*s*.).

In recent years the progress of genetics and cytology on the one hand, and of physics and organic chemistry on the other, has made it possible to pin biology, or a large part of it, on to a physical framework. Physicists and chemists have lost no time in exploiting this new advantage. The ultra-centrifuge, the X-ray tube and the ultra-violet microscope have been pressed into service and recently have been winning fresh victories every year. But the new situation gives scope for abstract thought as well as for practical action. The general type of molecular configuration in the cell nucleus which determines heredity and development can now be specified. Its properties are unique and their uniqueness is both physical and biological in its importance. The new branch of science built around them is "easily the most interesting of our day." That is the point of view with which Professor Schrödinger approaches the new knowledge of biology in his book.

The book is based on lectures given in Dublin in 1943. It begins with a lively description of the mechanism of heredity. We might scarcely expect an authority on wave-mechanics to write an authoritative account of the foundations of genetics. But that in fact is what Schrödinger has done. Perhaps being the son of a botanist has given one physicist an ease and confidence in handling the biological data that other physicists could not so readily acquire. However that may be, the result is a success. It will serve as an introduction to the subject to those on either side of the fence. There must be many who take university degrees in botany and zoology and know less of the principles of biology than Professor Schrödinger can tell them in this little book.

The second part of the argument is an attempt to discover how the molecular configuration in the cell nucleus has come to carry, in his phrase, the hereditary code-script of the 4-dimensional pattern of the organism. And, in doing so, how it has enabled life to get away from the drawbacks of quantum indeterminacy and to live, in some respects, outside the world of physics. Its success he attributes to the prodigious orderliness of the chromosome molecule. In other words integration defeats indeterminacy and escapes entropy.

Finally Professor Schrödinger arrives, where other physicists have arrived more hastily, at the door marked "Free Will". What he finds when he goes in is not pure mathematics but, strangely enough, almost pure biology. That is a revolution in itself.

There is one cavil to make. The text books tell us, and Schrödinger follows them, that continuous variation is not inherited and that Darwin was wrong in supposing it could be selected. We now know that there are genes, inherently too small to isolate as individuals, whose differences control such variation where inbreeding has not excluded them. So that Darwin was largely right, and De Vries largely wrong.

Lastly we may ask: is this all? Biology shows us integration passing from one level to another and reversing as it goes the appearance (or, as the reviewer would say, the *illusion* of indeterminacy). Atomic indeterminacy is straightened out well enough by the molecule. But at the microscopic level we again have the illusion produced by the false randomness of crossing over. And again at the individual level we have a control of these events which is fitted to a determinate adaptation. It is so fitted, however, subject to the statistical laws of natural selection acting indeterminately at the population level. Professor Schrödinger has shown us the first steps on this way. We may hope that he will be willing very soon to conduct us further.

C. D. Darlington.

Adult Education for Democracy. By Harold C. Shearman. (Workers' Educational Association, London; pp. 96; 3*s*. 6*d*.).

As one would expect from the W.E.A.'s Educational Officer, this little book adequately traces the closely woven pattern of the growth of adult education in this country. It rightly stresses again and again the principle that education for adults must be free from control; that is, the inspiration, choice of subject for study, and choice of tutor whenever possible, should come directly from the group of adults wishing to undertake a particular piece of study. That principle is perhaps the chief difference between educating children and adults, and hence it is one of which local education authorities in general have as yet little practical experience.

One could say, perhaps, that Mr. Shearman is not quite bold enough in the projection of his argument, but his reply to that charge would be that the Regulations for Further Education are still under review, and that no good purpose would be served by exposing the full strength of his case before the battle of Belgrave Square is fully joined.

That adult education is going to play an increasingly strong role in providing in this country a fairly well-informed citizenship is acknowledged by most educationists and by many politicians. It is essential, therefore, as indeed Mr. Shearman insists, that scholarship and integrity of educational purpose be criteria in the appointment of tutors for adult classes; the lofty hood of educationists should not degenerate into a bonnet that hives particular bees.

In the meantime scientists should consider how best to cultivate this vast field of adult education, for it is an important one; and an examination of subjects taken by adult classes in any year reveals that science is very far down the list. It would be interesting to learn whether this is because demand for scientific subjects is poor or whether the number of first-class science tutors available is small. Perhaps an energetic group of scientists would examine this question as part of their group programme.

P. V. Daley.

The Battle for Health. By Stephen Taylor. (Nicholson and Watson; 5*s*.).

"Like many other things in Britain, the health services look bad on paper, but work well in practice." This is a surprising statement to find in any book published at a time when reform of the existing medical services is generally regarded as a first step towards the new world. Surprising perhaps, but true. If this country were a fascist state we should all have been told these facts a thousand times. They would be brandished in triumphant speeches, stamped in capital letters on every poster on every wall. But we are a democracy and democracies are modest about their achievements. Despite this, if democracy is to work well, if it is to maintain its task, continually fashioning something new and better from the worn inheritance of the past—then the public must know the facts.

Stephen Taylor has told the story of Britain's battle for health in such a way that it is hard to put the book down. He is a doctor, but has discarded the birthright of his profession so far as to write in language which anyone can understand.

In 1774, 85% of the inhabitants of Chester had suffered from small-pox at some time in their lives; in 1924, there were only 2,500 cases in the whole of England and Wales. During the Boer war, typhoid killed more soldiers than died of wounds; by the war of 1914-18, the incidence of typhoid had been halved and the death rate reduced to one seventh of its former value. Fifty years ago, *you* would have had three times the chance of dying from tuberculosis of the lungs that you now have. These are the achievements of scientific research, medical practice and social organisation.

But the battle for health is not over. In 1942 some 1,500 children died of diphtheria. The same number died of bovine tuberculosis in 1941. And yet all these deaths were preventable. 20,000 people still die from tuberculosis of the lungs every year; the death rate from this disease among people living in back-to-back houses is known to be twice that for the inhabitants of comparable ordinary houses; but there are still back-to-back houses in our towns.

This book reminds me of two others I read some time ago. If you find it interesting, read also Paul de Kruif's *The Microbe Hunters* and M'Gonigle and Kirby on *Poverty and Public Health*.

B. D. Burns.

Far and Near

Council for Promotion of Field Studies

THE annual report of the Carnegie Trust discloses that a grant of £2000 has been promised to the Council for the Promotion of Field Studies towards the initial cost of adapting and equipping a pioneer field centre at Flatford Mill, Suffolk, a building long famous through its appearance in several paintings by Constable.

The aims of the Council for the Promotion of Field Studies, which was established in December 1943, are to provide facilities for every aspect of field work—for artists and archaeologists as well as naturalists and geologists—and to set up for this purpose throughout the country residential Field Study and Research Centres. These centres will be in localities selected for the richness and variety of their ecological features, geological and geographical interest and archaeological and historical importance; they will be available alike to all serious field workers, whether amateur or professional, whether as individuals or as members of a class from a school, training college, university, young people's college, youth club or other corporate body. It is the Council's intention to co-operate closely with local societies and field clubs.

Flatford Mill, to be set up as the first of these field centres, was offered to the Council, on lease, by the National Trust.

The Council has an executive committee (of which Professor W. H. Pearsall, F.R.S. is chairman) and a general committee on which are represented such bodies as the Association of Assistant Masters, the British Association, the British Ecological Society, the Natural History Museum, the Geological Society, the Linnean Society, the Institute of Archaeology, the North Western Naturalists' Union, the Royal Society of British Artists and the South Eastern Union of Scientific Societies, as well as 12 universities and 5 university colleges. The minimum annual subscription for membership of the Council is 5*s*.

Plans for Facilitating Research

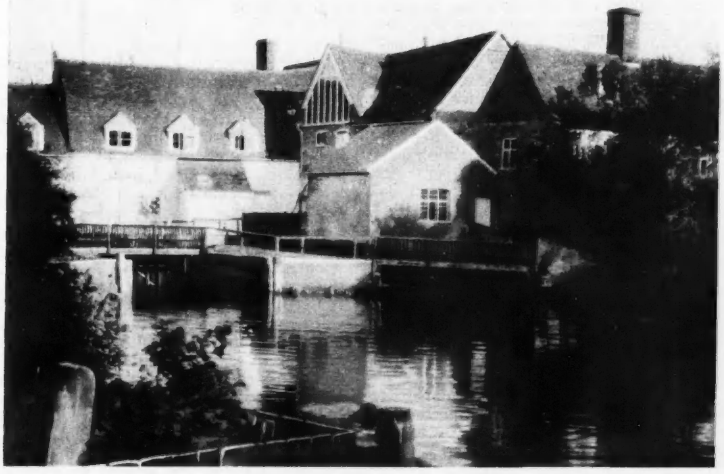
A TWO-DAY conference to discuss the future of research was held at Cambridge on March 17 to 18. Many of the speeches dealt with familiar themes, but the last session dealt with facilities for research—the material and organisational considerations which if neglected lead to wasted effort—and ventilated a number of points that have been somewhat overlooked in previous conferences.

The obvious yet too often ignored fact that laboratory technicians are indispensable was stressed by several speakers. Dr. J. E. Smith, for instance, said that it was estimated that the zoology department of Cambridge University could use 25 assistants; photographers, electricians, microtomists and keepers of animals were essential. "Many research men have to be one-man shows and know something about everything. There should be a certain amount of decentralisation of facilities to overcome this", he said.

Dr. B. C. J. Knight emphasised that modern research requires subdivision of labour; an increasingly complex technique is needed and so the place of the skilled technician becomes more important. The technician, said Dr. Knight, may range from those doing repetitive analyses to the more specialised glass worker, mechanics, pathological workers, and organisers of laboratory services—laboratory stewards or storekeepers. The problem at present is how this is to be made a worth-while career with a recognised status. Quite often laboratory assistants find themselves in dead-end jobs and so it is often impossible to recommend the work as a career. They should have facilities for continuing their education, time off with pay being allowed. Training should be given in special techniques. Part-time study cannot be looked upon as likely to attain a degree level; it is often done, but the dice are heavily loaded against those who have a full-time job and only the tough ones get through. Specialised training is a little more difficult to organise and should probably be done on a personal basis. There should be a diploma and qualifications. The Royal Photographic Society has one such qualification. "Science is going to require a large number of technicians and the only way to get them is to make the profession a recognised one", concluded Dr. Knight.

Dr. S. R. Elsden spoke of the need for centralising facilities, instead of relying on the present system under which each science department of a university is a separate unit, resulting in a certain amount of overlap and duplication and preventing the full use of the available equipment. Centralisation would save money and increase convenience. It would make possible bulk purchases, and Dr. Elsden gave some figures to indicate the extent of savings that could be effected; bought by the winchester ether costs 3s. 5d. a lb., nearly twice as much as when bought by the hundred-weight; discount for a case of 60 beakers is 10% as against 25% when 40 cases are purchased. A large purchasing organisation could be a powerful weapon in forcing up the very low standard of British analytical chemicals which do not compare with American and German standards. As an example the speaker quoted the case of a sample of thallium hydroxide ordered from a certain firm which proved to be 80% thallium carbonate; on complaint to the firm the excuse was that the hydroxide was an "unstable substance". Dr. Elsden argued the case for centralised workshops, particularly for the biological laboratories, The skill and standard of engineering equipment would then rise, and the junior assistants would stand much better chances of advancement, he predicted.

The training of laboratory assistants was raised by Dr. Wooster who described the present position as very bad. He mentioned the University of Leyden which 20 years ago produced a very fine scheme of laboratory training, so that not only did laboratory assistants of Leyden University train there but also people went there from all over Holland and indeed from all over the world. Dr. Wooster was opposed to the idea of centralised workshops in the university—"I always find that the nearer a lathe is to my hand the quicker the work progresses," he commented.



The Council for the Promotion of Field Studies is to set up its first field centre at Flatford Mill

Dr. Marjory Stephenson

Dr. Kathleen Lonsdale

Royal Society elects Two Women

UNTIL this year Queen Victoria was the only woman to become an F.R.S., the honour in her instance falling in line with the customary practice of electing the ruling monarch to membership of the Royal Society. This year's list of newly-elected fellows is historic in that it sets the precedent for the election of women scientists to fellowship of the Royal Society, whose choice of DR. KATHLEEN LONSDALE and DR. MARJORY STEPHENSON as the first women to receive recognition in this way for their contributions to science is calculated to give general satisfaction. Both have done research of distinction, Dr. Lonsdale, of the Royal Institution, in the field of X-ray crystallography and Dr. Stephenson, the Cambridge biochemist, on bacterial metabolism.

It is interesting to recall that as long ago as 1902 a woman, Mrs. B. Ayrton, was nominated for election, but when the Royal Society took counsel's opinion it was ruled that women were not eligible for election. As Sir Henry Lyons records in his recently published history of the Society's administration this disqualification was removed by 1923. From that year onwards both men and women have been eligible, but to make the position quite clear a postal ballot was held last year and as a majority vote was obtained on that ballot the Society's statutes were amended and all doubts removed as to whether women were eligible for election.

The names of the other eighteen F.R.S.'s elected this year are as follows:

LEONARD COLESBROOK, bacteriologist; WILLIAM SCOTT FARREN, director of Royal Aircraft Establishment; NORMAN FEATHER, Physicist, university lecturer; JOHN HENRY GADDUM, professor of pharmacology, Edinburgh; HARRY GODWIN, university lecturer in Botany, Cambridge; JOHN MASSON GULLAND, Professor of Chemistry, Nottingham; HILDEBRAND WOLFE HARVEY, marine biologist; VINCENT CHARLES ILLING, professor of Oil Technology, Imperial College of Science and Technology.

ALBERT EDWARD INGHAM, university lecturer in mathematics, Cambridge; HERBERT DAVENPORT KAY, director of the National Institute for Research in Dairying; WILFRED BENNETT LEWIS, physicist, university lecturer, Cambridge; PRASANTA CHANDRA MAHALANOBIS, founder of the Statistical Laboratory, Calcutta; RUDOLF ERNST PEIERLS, professor of applied mathematics, Birmingham.

JOHN MONTEATH ROBERTSON, professor of chemistry, Glasgow; FREDERICK MAURICE ROWE, professor of colour chemistry and dyeing, Leeds; WILLIAM WRIGHT SMITH, Regius professor of botany and keeper of the Royal Botanic Gardens, Edinburgh; BARNES NEVILLE WALLIS, chief of Research and Development, Armstrong Vickers (Aircraft Section), and JOHN ZACHARY YOUNG, University Lecturer in Zoology, Oxford.

Personal Notes

BY a coincidence, the announcement of MR. B. NEVILLE WALLIS's nomination for fellowship of the Royal Society was made on the same day that the first use of the 10-ton bomb designed by him was reported. In a broadcast to America a day or two later Mr. Wallis disclosed that PROFESSOR P. M. S. BLACKETT was responsible for devising the semi-automatic bombsight (its development he credited to the Royal Aircraft Establishment) upon which depends the accurate release of this bomb.

Science for the Citizen—4

As a supplement to the "Education and Vocational Training" courses which the Navy, Army and Air Force are arranging, the B.B.C. is to broadcast each week no fewer than 18 programmes of an educational character. These will deal with a wide range of subjects, including science, and will bear the same sort of relation to E.V.T. courses as does school broadcasting to classroom teaching. Rumour has it that the B.B.C. is looking for a scientist to direct the B.B.C.'s efforts in this new attempt at scientific exposition. If that rumour proves to be true then it will be a welcome sign that Broadcasting House admits the validity of recent criticism of science broadcasts and that it recognises the need for improving liaison with the scientific world. A liaison officer who would be *persona grata* with scientists is badly needed. There are quite a number of people both inside Broadcasting House and outside it who could do the job.

One hopes that when it comes to preparing these broadcasts for the Forces the B.B.C. will aim at a high standard of factual accuracy. Perhaps more important, the producers responsible for programmes dealing with various aspects of scientific progress should seek to achieve a better sense of balance and proportion in this kind of presentation which if it is to make full use of radio as a separate medium and not reduce it to a mere projection of the lecture platform, must be to a large degree impressionistic.

With broadcasting any inaccuracies in detail and false impressions reach a public numbering many millions. As there is no such thing as a broadcast "correspondence column" most of the mistakes remain uncorrected, though a few, one is glad to admit, are put right in the correspondence columns of *The Listener* and *The Radio Times*. We are prompted to call attention to this particular aspect of the responsibility for accuracy because of the unsatisfactory answer that a DISCOVERY reader had when she pointed out an error of some magnitude that occurred in "Rear Ranker's" talks on plastics. "Rear Ranker" had given the impression that milk is divisible into two parts, one of them nutritious and the other—the casein—a useless waste product that fortunately can be used for making plastics. Seemingly a number of listeners objected to this suggestion, for our reader received an obviously duplicated letter from "Rear Ranker" who seemed to be annoyed that there should exist a desire for accuracy in technical matters. One passage of his letter went as follows: *Scientists notoriously disagree. Even supposing a string of extracts word for word from technical dictionaries or encyclopædias were permitted to go out as a broadcast of incredible dullness somebody would still cavil at the script.* Admittedly radio presentation calls for a very different manipulation of words than would be performed in writing an article for, say, *The Times*, *The Daily Mirror* or *Discovery*, and effective radio impression may result in unorthodox verbal effects, but there is no room on the air for science broadcasters whose attitude towards facts is flippant, though a lightheartedness towards them (which generally comes only where there is a good grasp of the subject on which one talks or writes) is a valuable antidote to stodginess.

The Photograph on the Cover

THIS month's cover photograph shows a synthetic sapphire building up stalagmite-fashion as pure alumina is fed through an intensely hot oxy-hydrogen flame. When the alumina meets the flame it melts, afterwards cooling and solidifying on a refractory column. By this technique (described in greater detail in DISCOVERY, November 1944, p. 350-1) a crystal about 50 mm. in length and 60 grams in weight (300 carats) can be produced in a matter of four or five hours.

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